Strumenti per la simulazione attività Monte Carlo e studi di fisica

Roberto Preghenella
Istituto Nazionale di Fisica Nucleare, Bologna

Giornata Nazionale EIC_NET
Bari, Italy
7-8 November 2019

preghenella@bo.infn.it

Attività

- sviluppo di **generatori di eventi** per eventi di diffusione elettrone-nucleone ed elettrone-nucleo

- studio delle potenzialità di un **rivelatore a tempo di volo** per l'identificazione di particelle a EIC

- **attività propedeutiche** per futuri contributi agli studi di fisica e rivelatori

- costruzione del programma di **spettroscopia adronica** a EIC

EIC Software Group

TS

The aim is to:

- Support EIC Physics and Detector Conceptual Development / Yellow Report
- Be ready for kick-off meeting in late 2019

Following the mandate to create a workflow environment for EICUG:

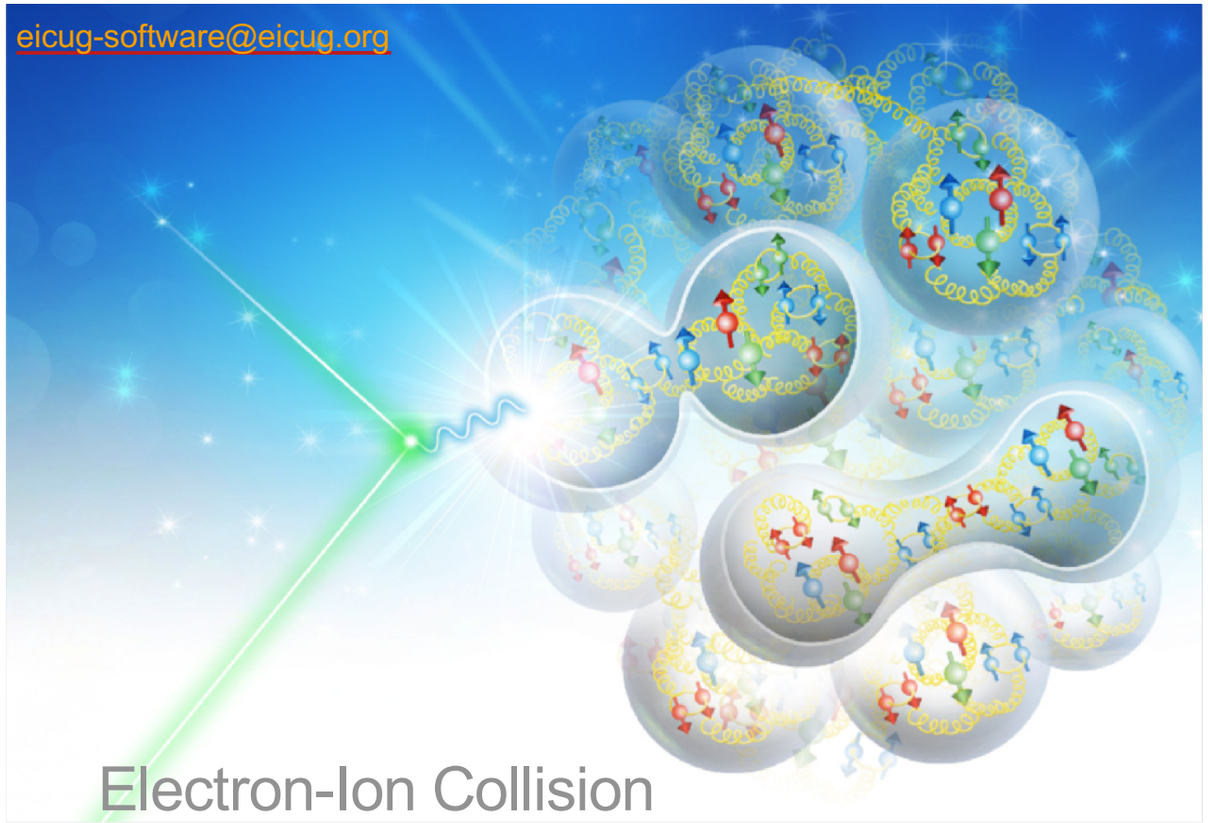
- **fast and full simulation tools** current focus: common Geant4 infrastructure with flexible accelerator and detector interface
- **documentation** tutorials and website in preparation
- **support** team being build up

Andrea Bressan (INFN, University of Trieste) co-chair

Markus Diefenthaler (EIC², Jefferson Lab)

Torre Wenaus (Brookhaven Lab)

eicug-software@eicug.org



BROOKHAVEN NATIONAL LABORATORY

Jefferson Lab

UNIVERSITÀ DEGLI STUDI DI TRIESTE

EIC Software Group

TS

covering all aspects

Simulation of physics processes

Simulation of detector responses

Physics analysis

EIC Software Group

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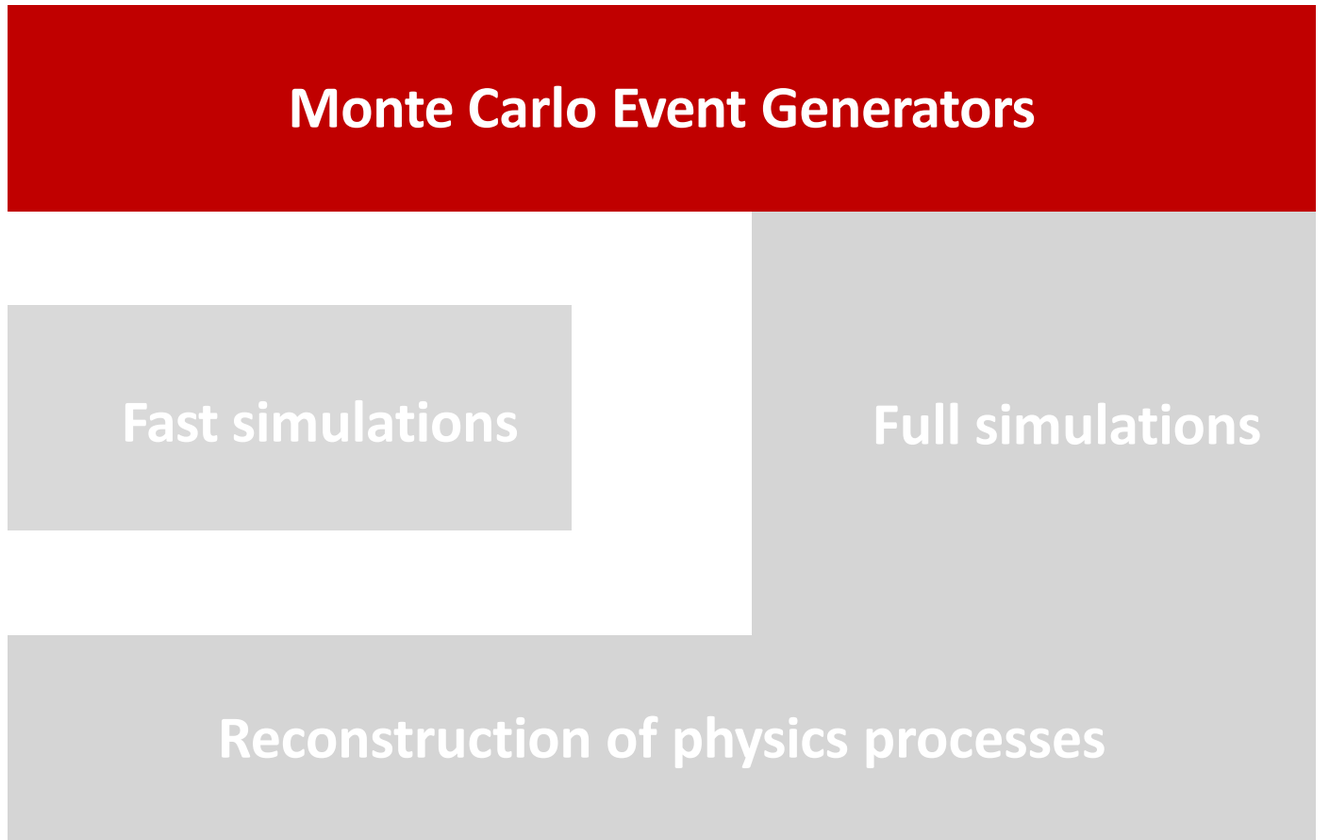
covering all aspects

Simulation of physics processes

Simulation of detector responses

Physics analysis



Organizzazione Workshops

TS

Workshop organized within the

- EIC Software Consortium
- EIC Software Working group (co-chair)

To discuss the needs of both upgrades for MC Event generators and needs of improved detector simulations

https://indico.desy.de/indico/event/22030/

https://agenda.infn.it/event/17249/

Organizzazione Workshops

TS

- MCEG for future ep and eA facilities
- **Dates** November 5-7 2019
- **Location** Erwin Schrödinger International Institute for Mathematical Physics in (ESI)
- Agenda

  We would like to focus the discussion on the simulation of eA processes but also follow up on the previous workshop (TMD MCEG, validation of ep simulations with HERA data).

EIC Software Group

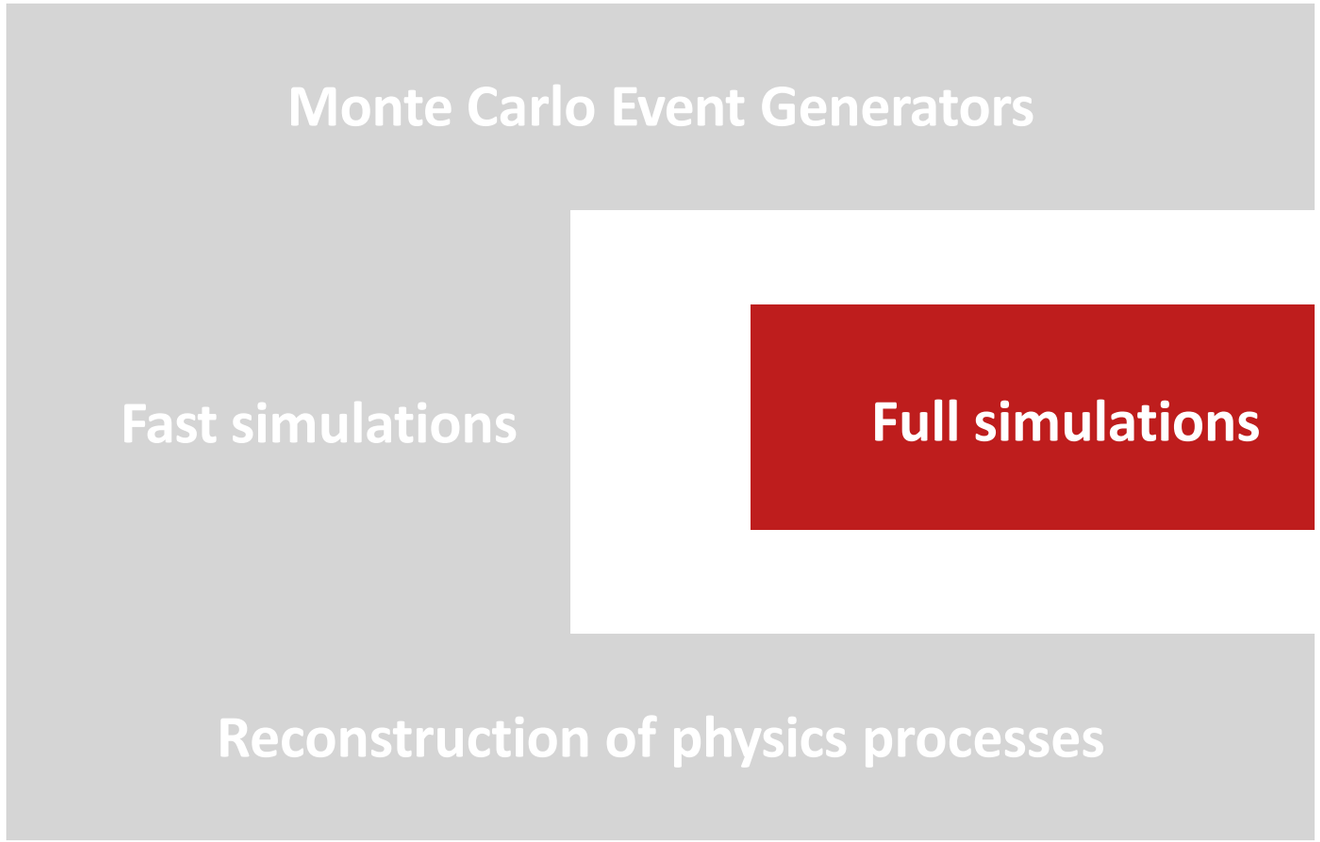
TS

covering all aspects

Simulation of physics processes

Simulation of detector responses

Physics analysis



EIC Software Meeting

TS

status review on common GEANT4 framework

- EIC Software Meeting (https://www.jlab.org/indico/event/339/)

EIC Software Meeting

chaired by Andrea Fressan (INFN Trieste), Markus Diefenthaler (Jefferson Lab), Alexander Kiselev (BNL), Torre Wenaus (BNL)

Tuesday, 24 September 2019 from **08:00** to **21:00** (UTC)
at **CEBAF Center (F324-325)**
CEBAF Center (Building 12) 12000 Jefferson Ave, Newport News, VA 23606

Description On Tuesday, September 24, an EIC Software Meeting will be held at Jefferson Lab. We will review the status of the simulation tools for the EIC and will continue the work from the EIC Software Meeting on July 10 on a common Geant4 infrastructure for the EIC that will allow geometry exchange between the eRHIC and JLEIC concepts and is compatible with existing simulations tools. The meeting will be in parallel to the 24th Geant4 International Meeting and end with a Geant4 Technical Forum on the EIC.

The U.S. Department of Energy requires all non-U.S. citizens to provide government-issued picture identifcation, i.e. green card, passport, visa, and U.S. Citizenship and Immigration Services information before entry to Jefferson Lab. Please contact Markus Diefenthaler (mdiefent@jlab.org) for an invitation letter.

Remote access will be available via BLueJeans: https://bluejeans.com/920347364

Material: Visiting Jefferson Lab

Tuesday, 24 September 2019

08:30 - 10:00	EIC Software	
	08:30	**Requirements and status of write-up** *45'*
	09:15	**Status of common simulation tools and next steps** *45'*
10:00 - 10:30	Coffee break	
10:30 - 12:00	Common Geant4 Infrastructure	
	10:30	**Discussion: Detector naming conventions** *45'*
	11:15	**Discussion: C++ infrastructure** *45'*
12:00 - 14:00	Lunch (on our own)	
14:00 - 15:30	EIC Software Initiatives	
15:30 - 16:00	Coffee break	
16:00 - 18:00	Technical Forum on EIC	
19:00 - 21:00	Dinner (on your own)	

24TH GEANT4 COLLABORATION MEETING

GEANT4
A SIMULATION TOOLKIT

Date:
September 23, 2019 to September 27, 2019

Conference location:
Thomas Jefferson National Accelerator Facility
12000 Jefferson Avenue
Newport News, VA, 23606 USA

https://www.jlab.org/conference/2019/Geant4Collab

Attività propedeutiche

obiettivi e gruppi coinvolti

- **Obiettivi**
  → acquisire competenze per utilizzare gli strumenti software di simulazione per studi EIC (fisica e rivelatori)
  → seguire evoluzione del gruppo software internazionale (EICUG-SWG)
  → preparazione per studi mirati nel prossimo anno

- **Gruppi coinvolti**
  → Bari (D. Elia, A. Mastroserio, G. Volpe)
  → Bologna (F. Noferini, R. Preghenella)
  → Torino (M. Chiosso, M. Ruspa)
  → Trieste (A. Bressan)

Attività propedeutiche

contatti con comunità internazionale

- **EICUG Software Working Group**
  - → riunioni mensili da remoto
  - → EIC Software Meeting (Trieste, May 2019)
  - → EIC Simulation Tutorial (Paris, Jun 2019)

- **Workshop su fisica e generatori**
  - → The Spectroscopy program at EIC (Trento, Dec 2018)
  - → MCEG for future ep and eA facilities (DESY, Feb 2019)
  - → MCEG for future ep and eA facilities (Vienna, Nov 2019)

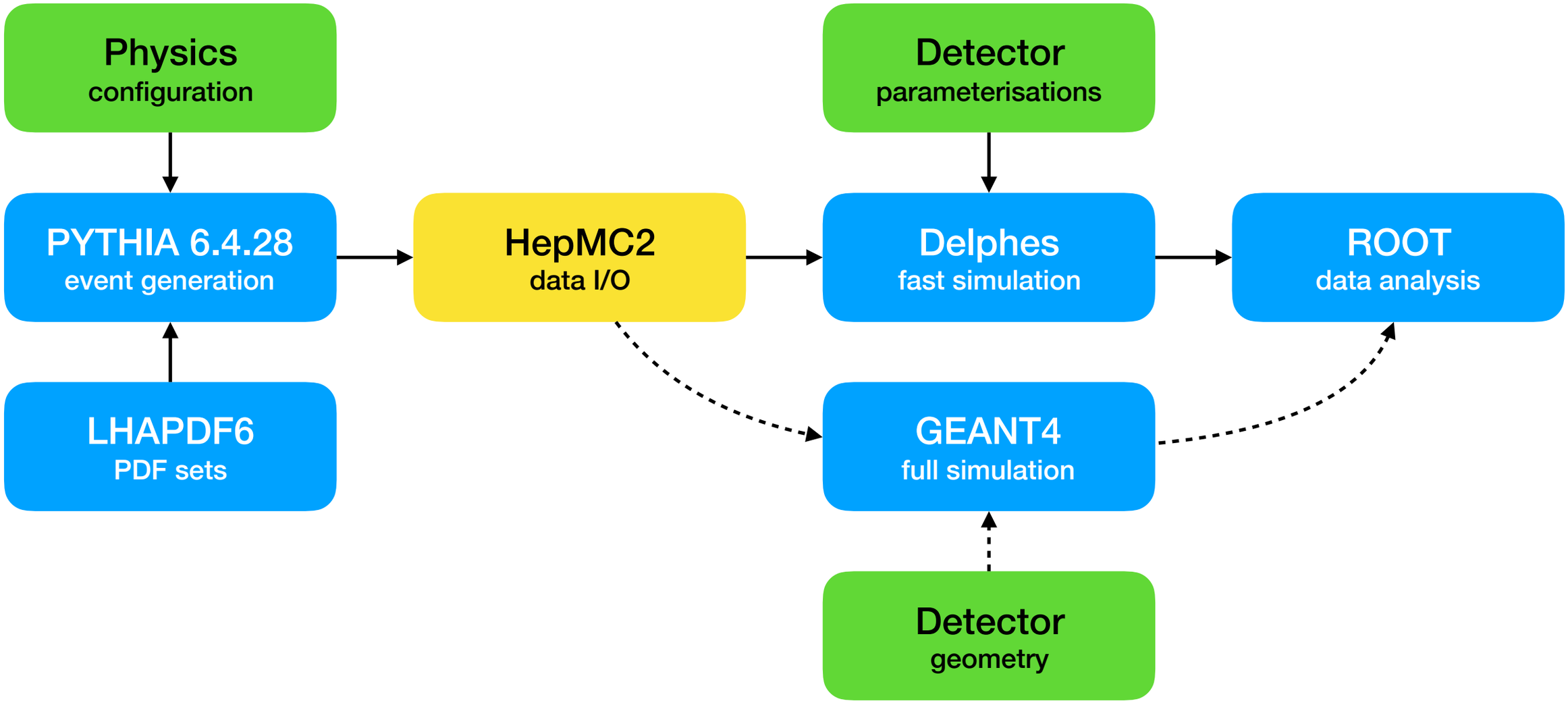
Attività propedeutiche

punti di indagine e prime esperienze

- **Generatori Monte Carlo**
  - → Pythia6, Pythia8, RAPGAP (more as per needs)
  - → supporto per compilazione codice (Docker containers)
  - → configurazione e selezione processi di fisica
  - → interfaccia con PDF sets (LHAPDF)
  - → interfaccia I/O con simulazione (HepMC)

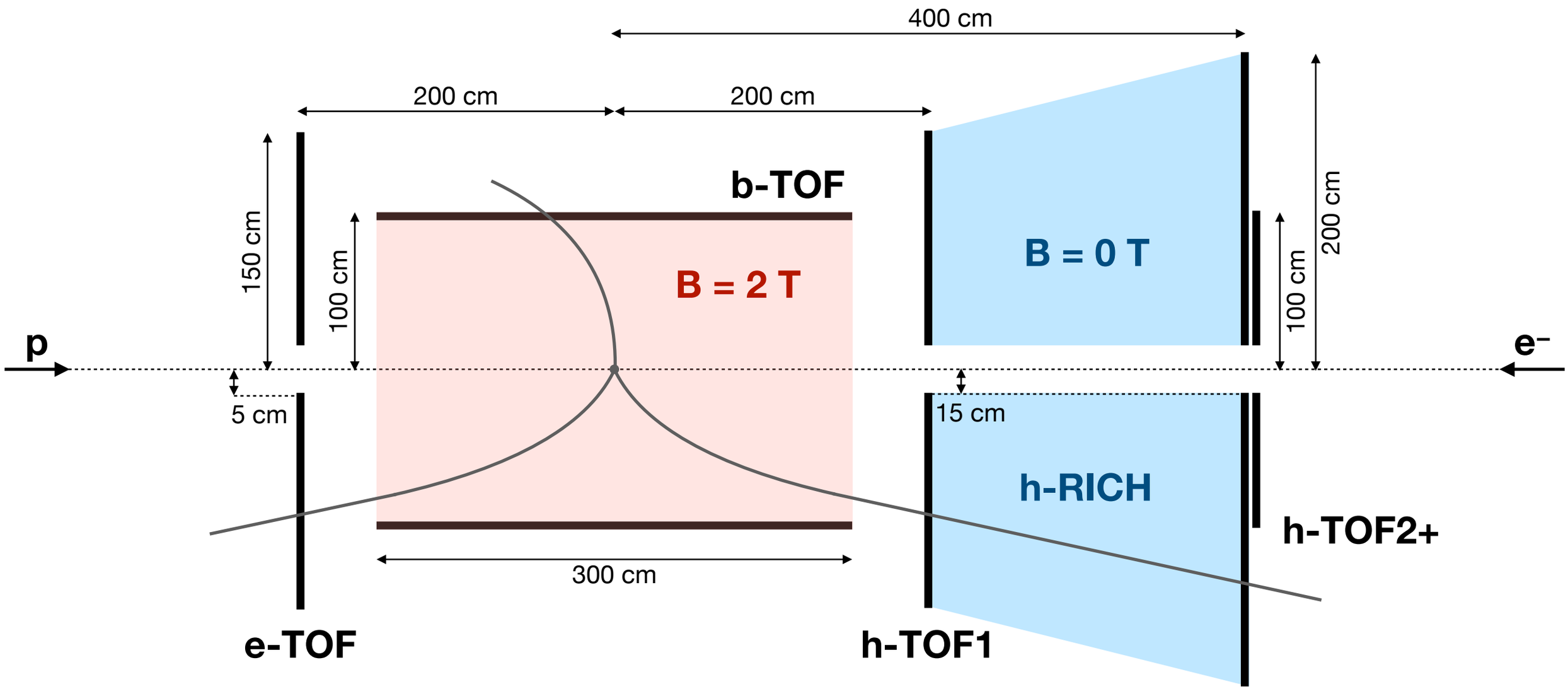
- **Simulazione**
  - → esperienza positiva con fast simulation (Delphes)
  - → da investigare strumento comune EICUG (eicsmear)
  - → seguire sviluppi EICUG-SWG per simulazioni GEANT4
  - → possibile sviluppo per utilizzo GEANT4 ad-hoc

Simulation tools at work



Study different TOF layouts

BO



	η_{min}	η_{max}	area (m^2)	σ_t (ps)
e-TOF	-4.1	1.1	7	20
b-TOF	-1.2	1.2	19	20
h-TOF1	1.1	3.3	7	20
h-TOF2	1.4	4.0	12.5	20
h-TOF2+	2.1	4.0	3 x 3	20 / √4

several potential configurations studied with emphasis on different phase-space and physics (η → x) coverage

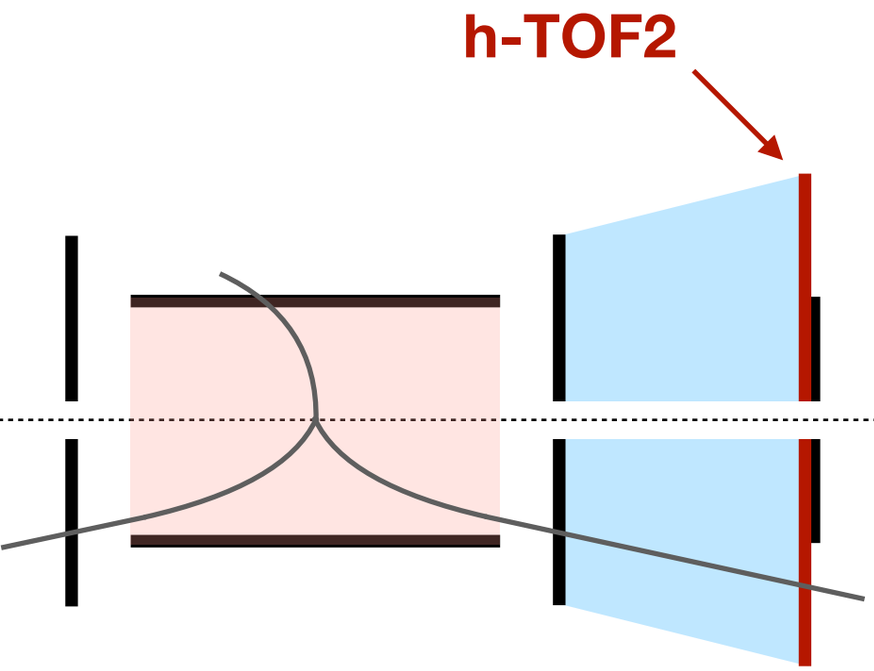
h-TOF2+ extension with 3 additional 20 ps layers at high-η for higher *p*

TOF performance

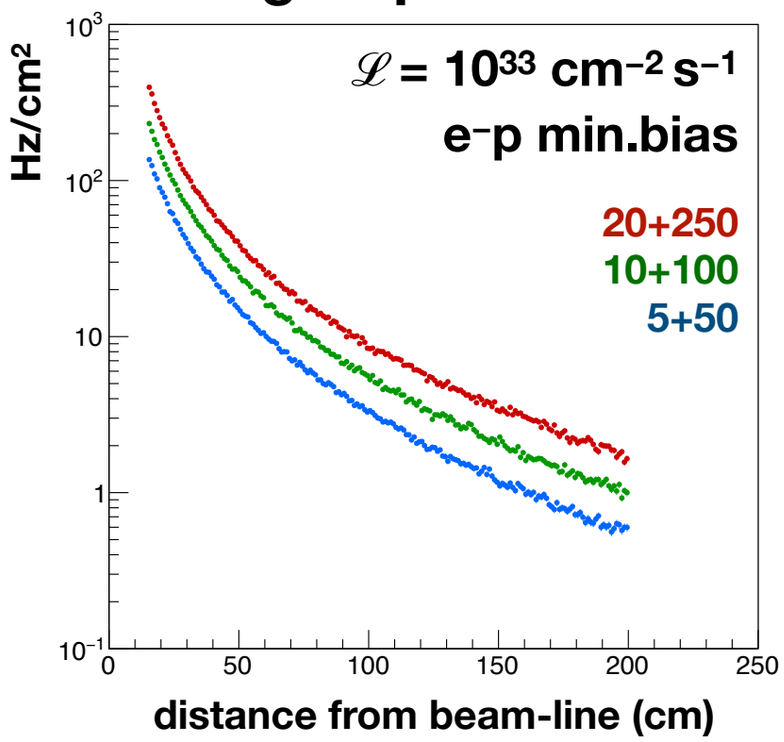
BO

h-TOF2 example

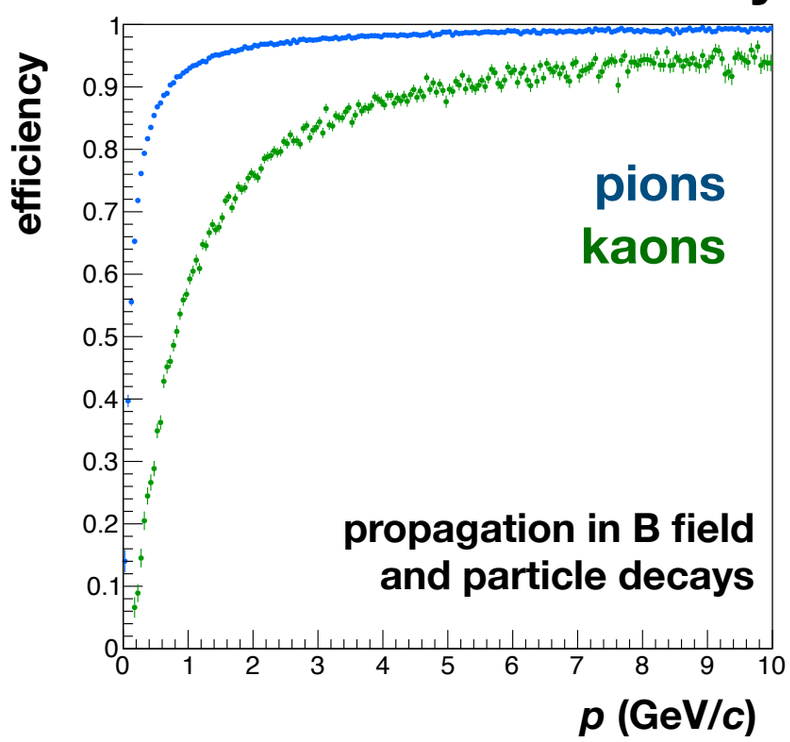
results also for other configurations



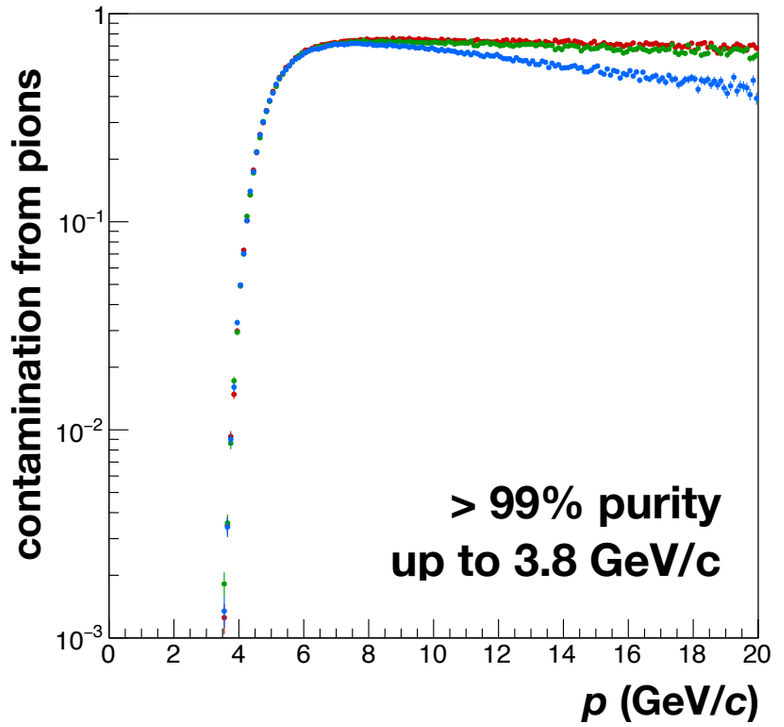
charged-particle flux

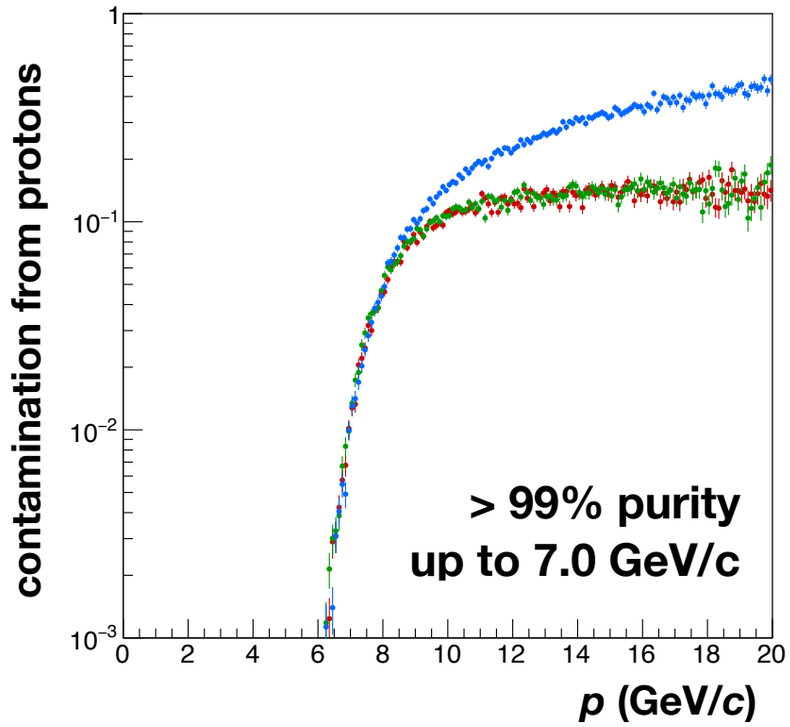


identification efficiency



kaon identification purity: 3σ PID selection

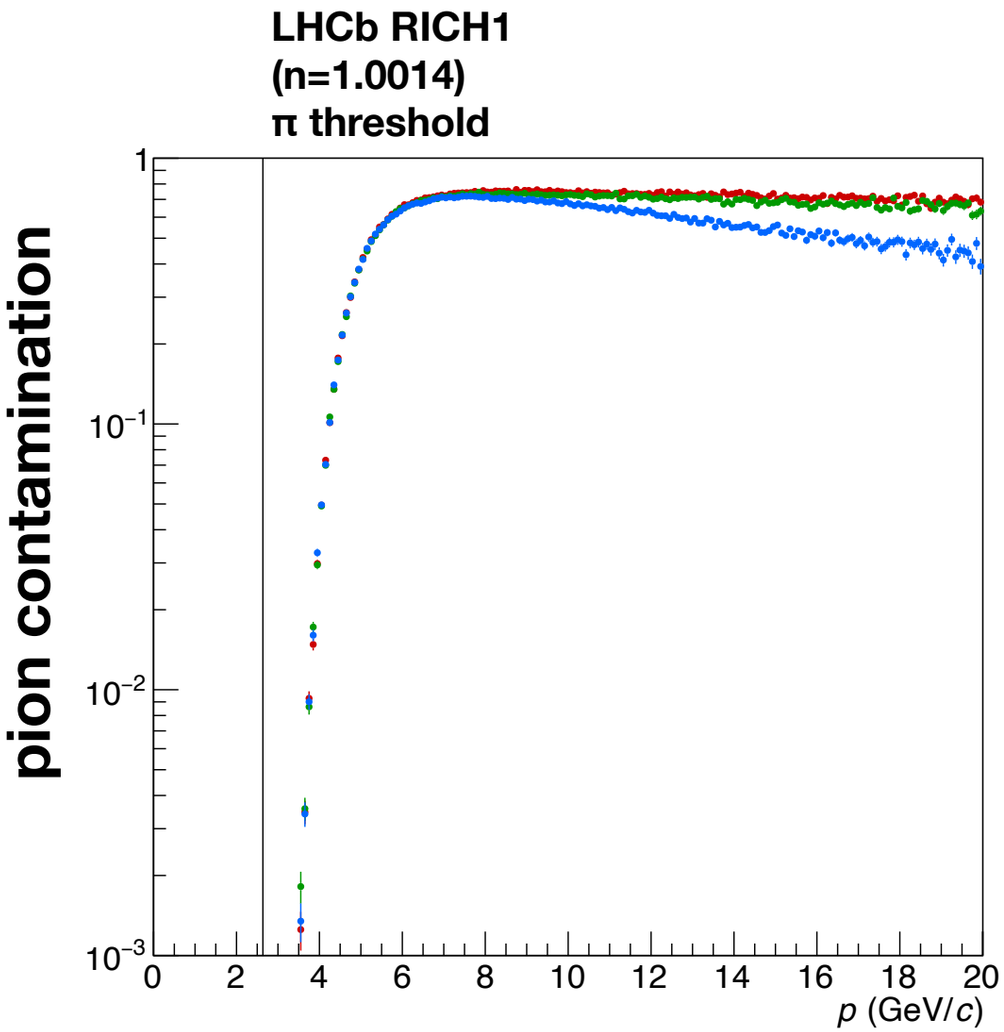




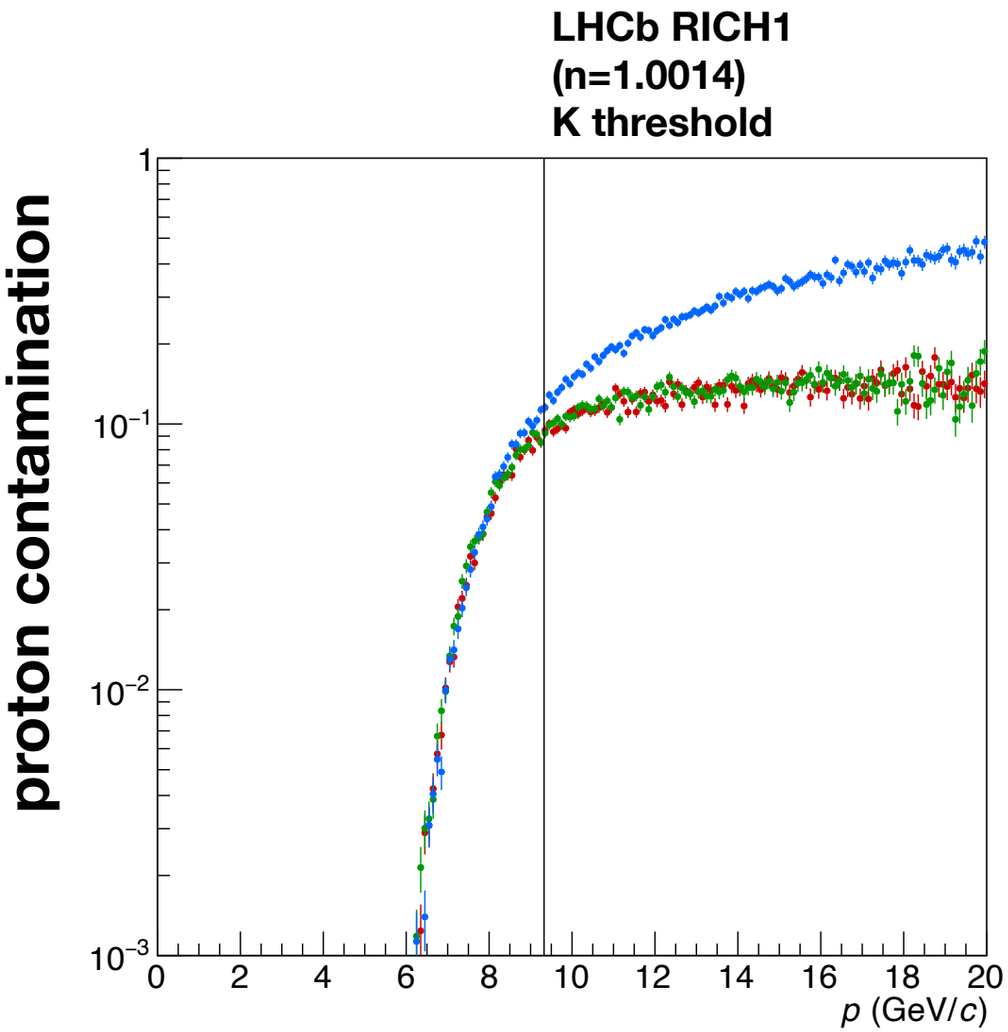
Kaon purity

BO

synergy: TOF+RICH for combined particle ID



100% purity for all momenta

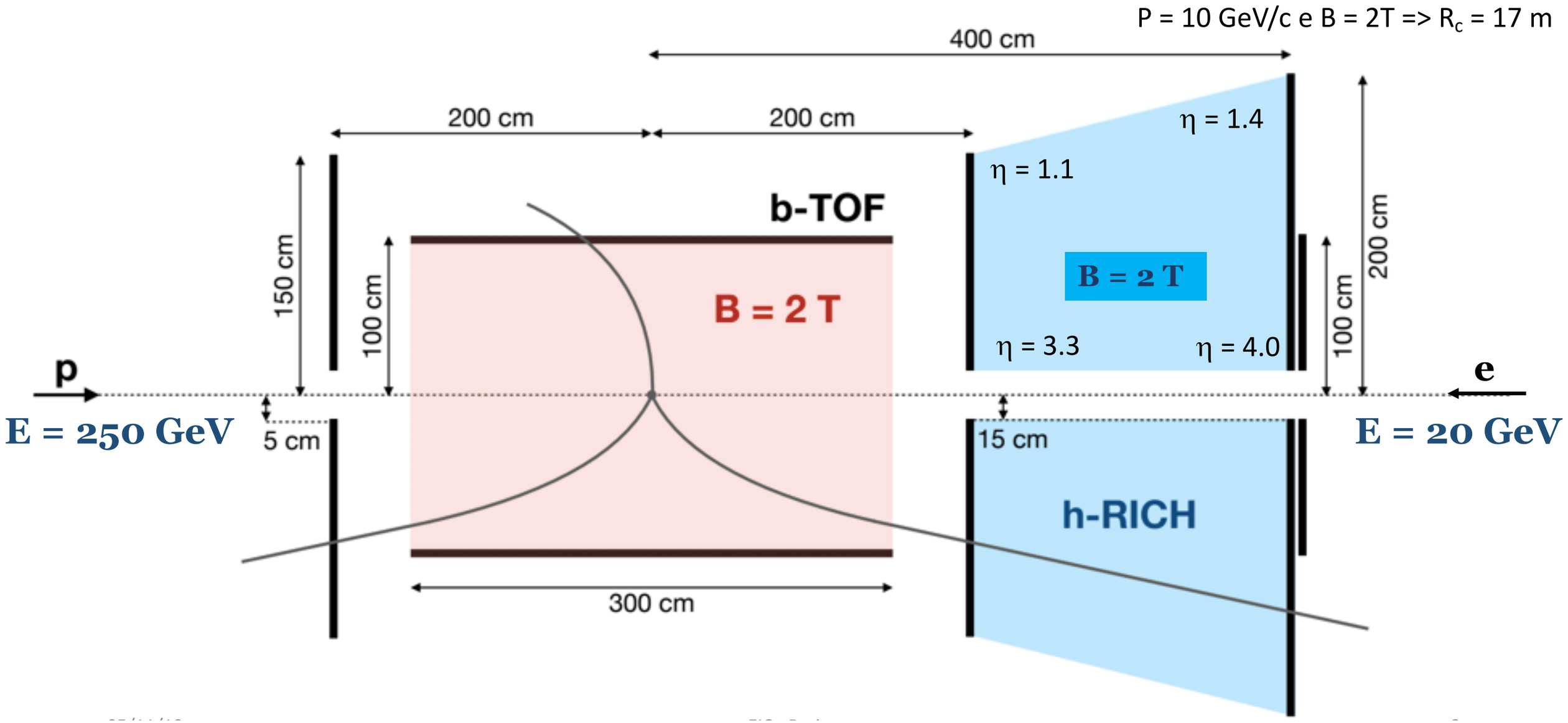


> 90% purity up to 9.5 GeV/c

Studi per RICH

BA

strumenti comuni allo studio TOF, simile layout

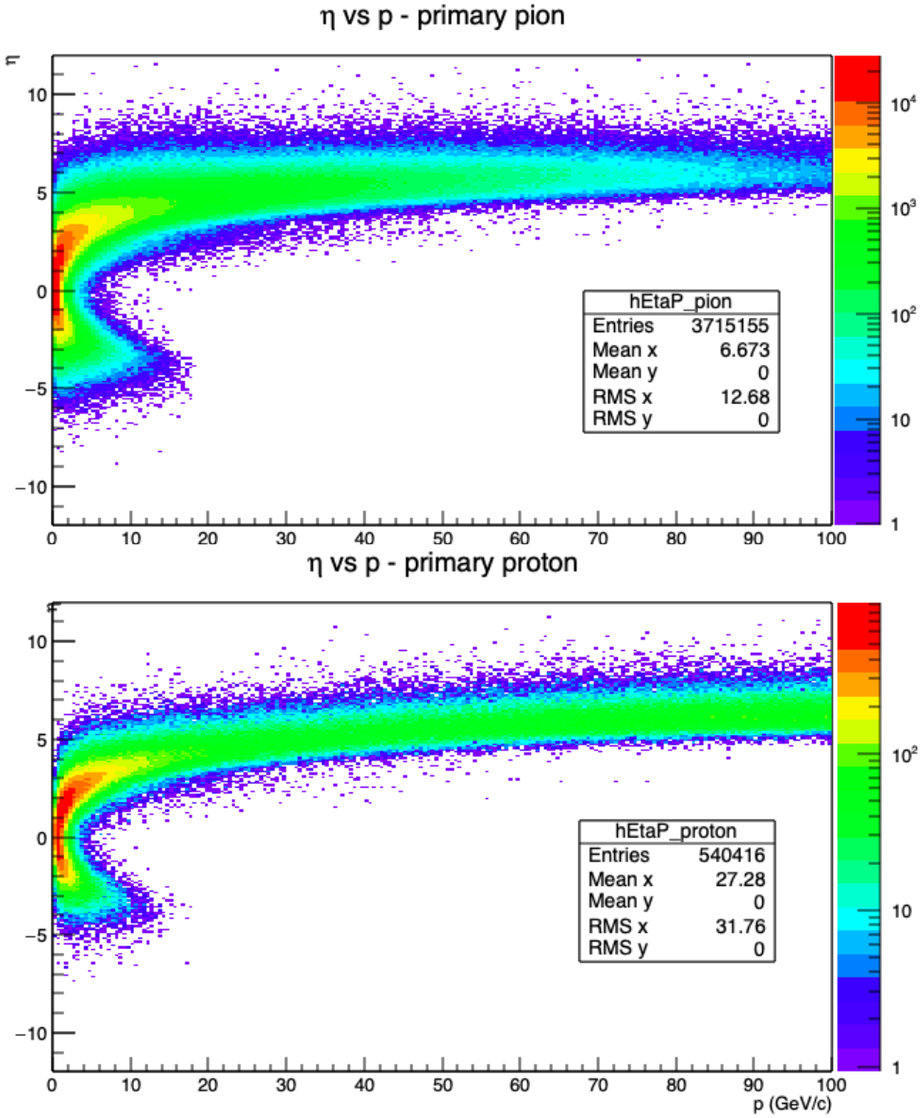


Studi per RICH

BA

produzione di adroni carichi primari (π, K, p)

PYTHIA 6.4.28
e⁻p collisions
20+250 GeV



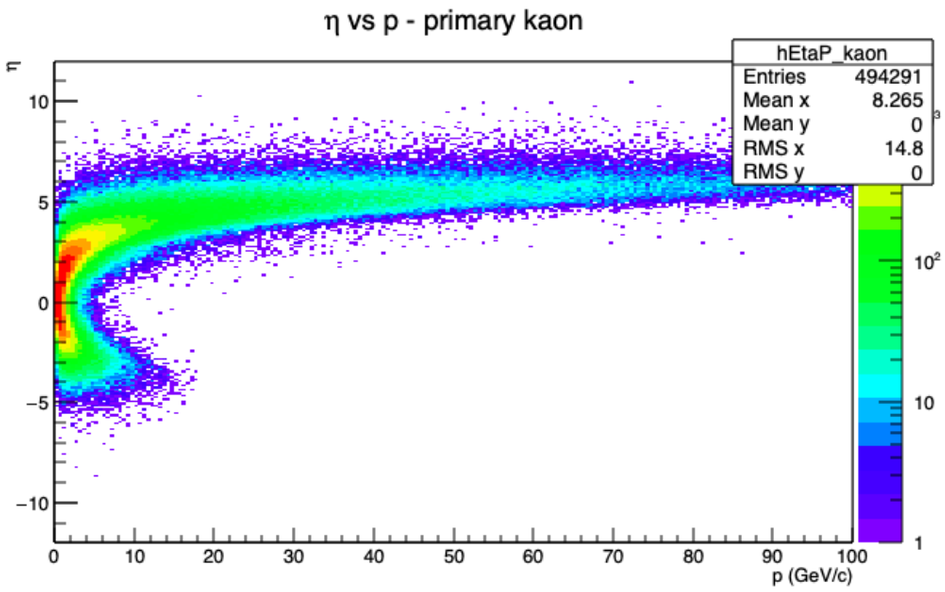
500k events = > primary charged hadrons (*)

$\langle N_\pi \rangle_{ev} \approx 7.4$

$\langle N_p \rangle_{ev} \approx 1.1$

$\langle N_K \rangle_{ev} \approx 1$

(*) within 1 cm from the interaction vertex

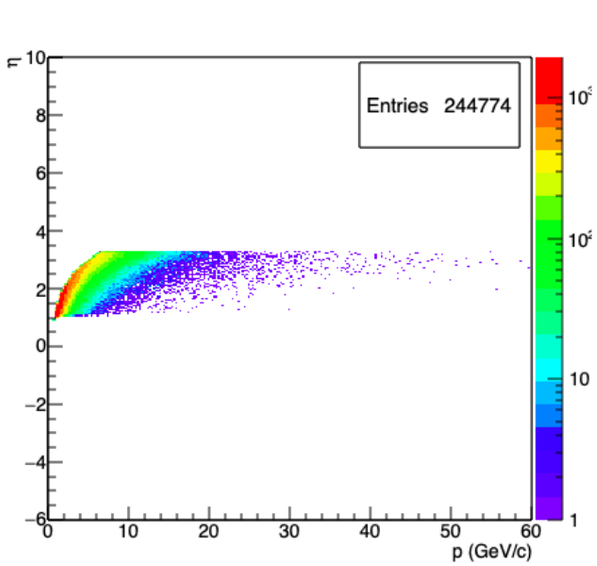


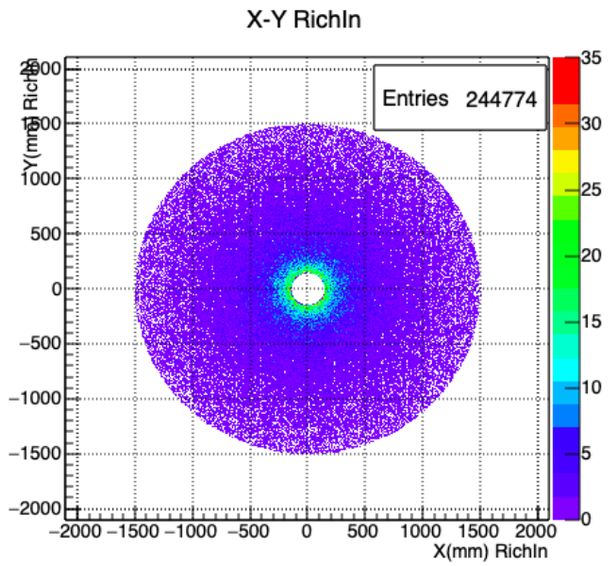
Studi per RICH

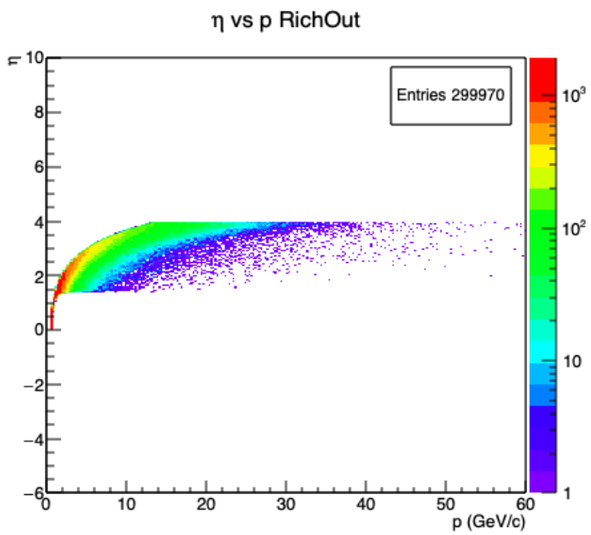
BA

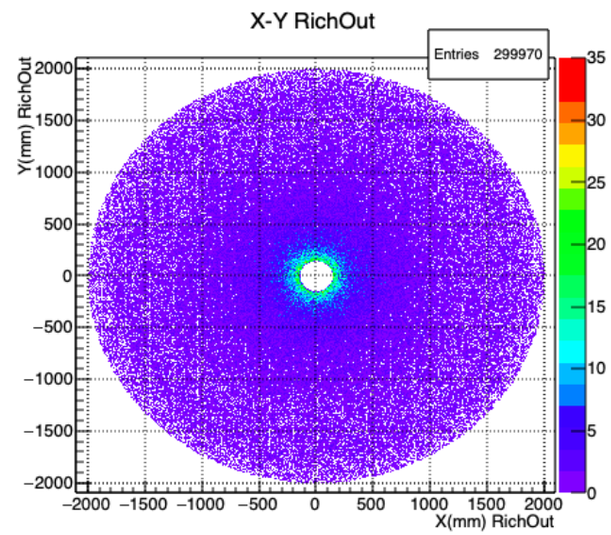
accettanza geometrica

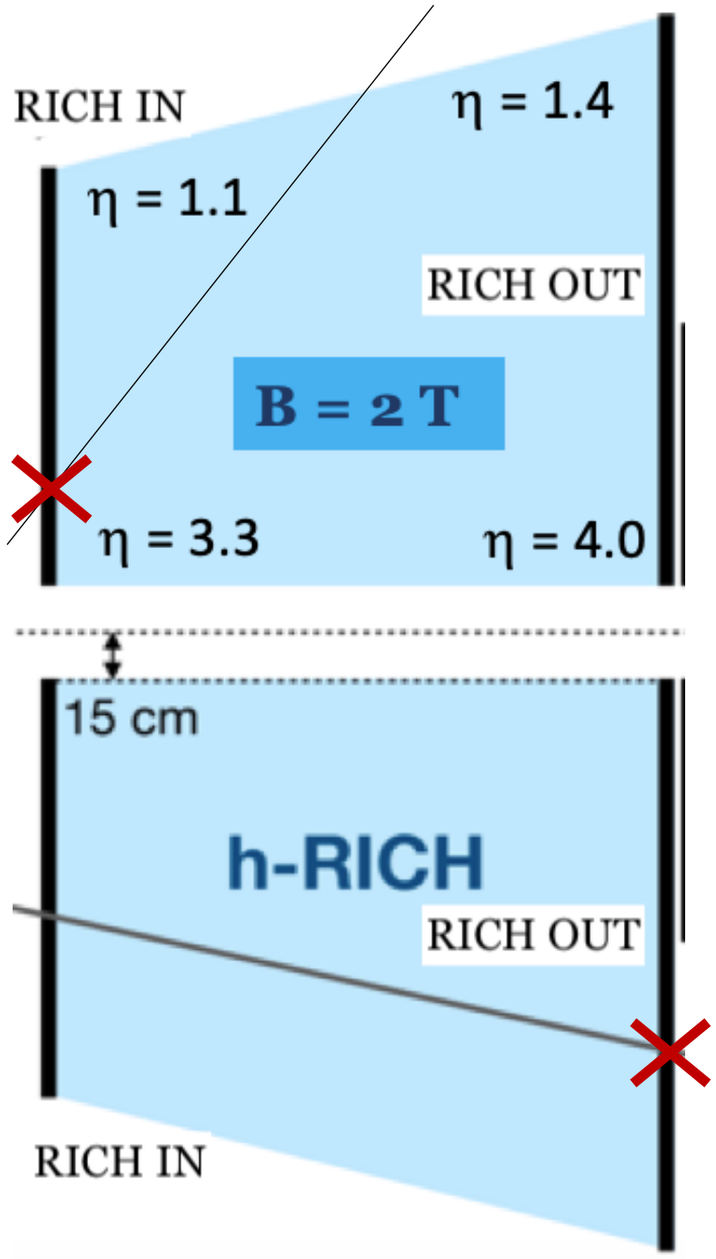
PYTHIA 6.4.28
e⁻p collisions
20+250 GeV











Studi per RICH

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accettanza geometrica

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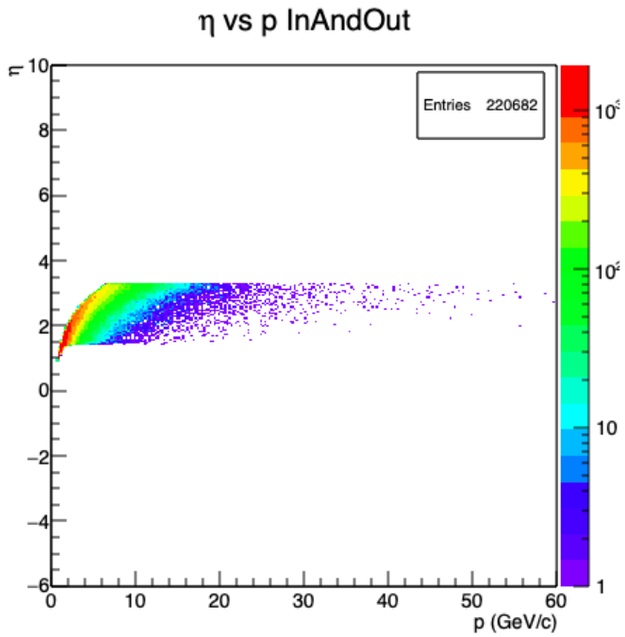
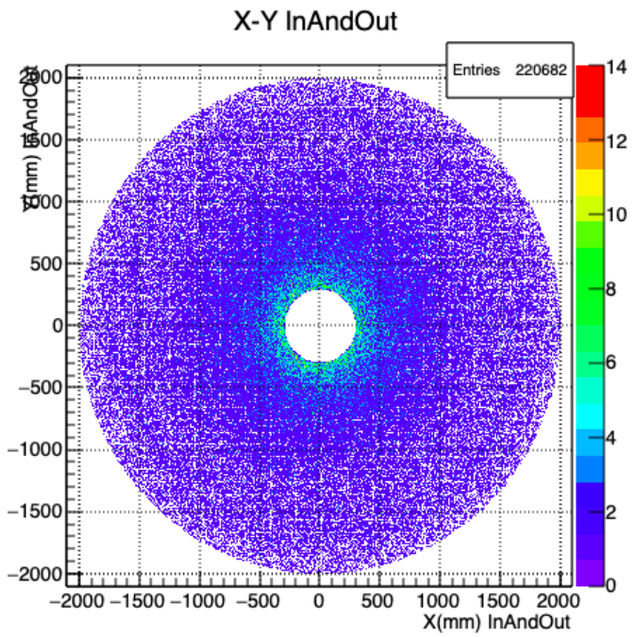
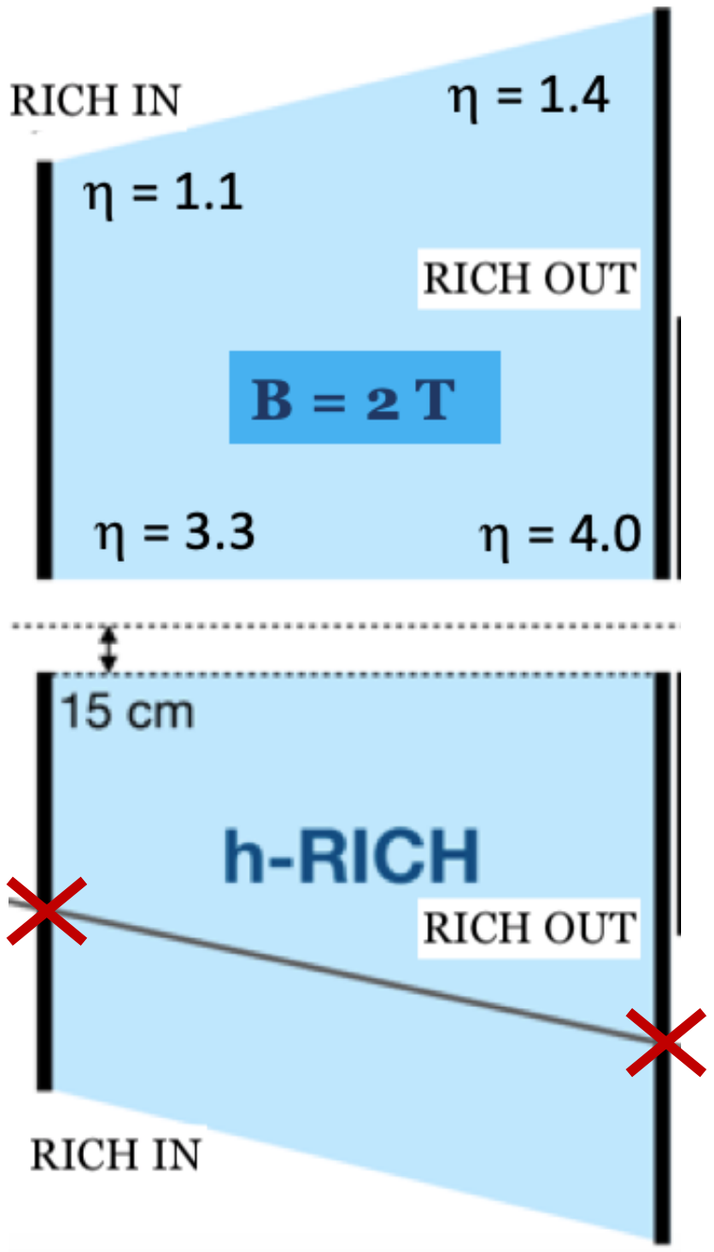




Per particle species
-> see next slide

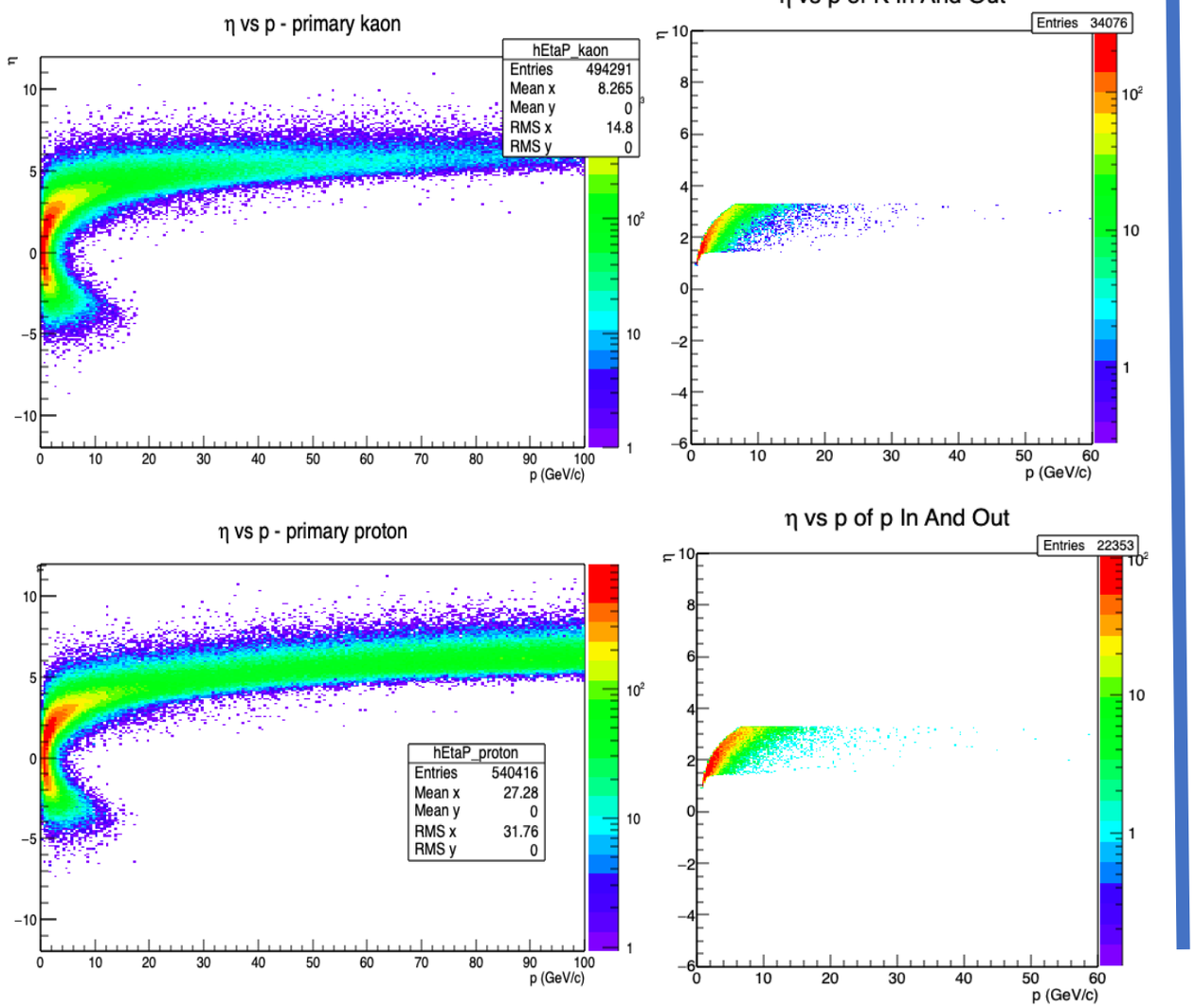


Studi per RICH

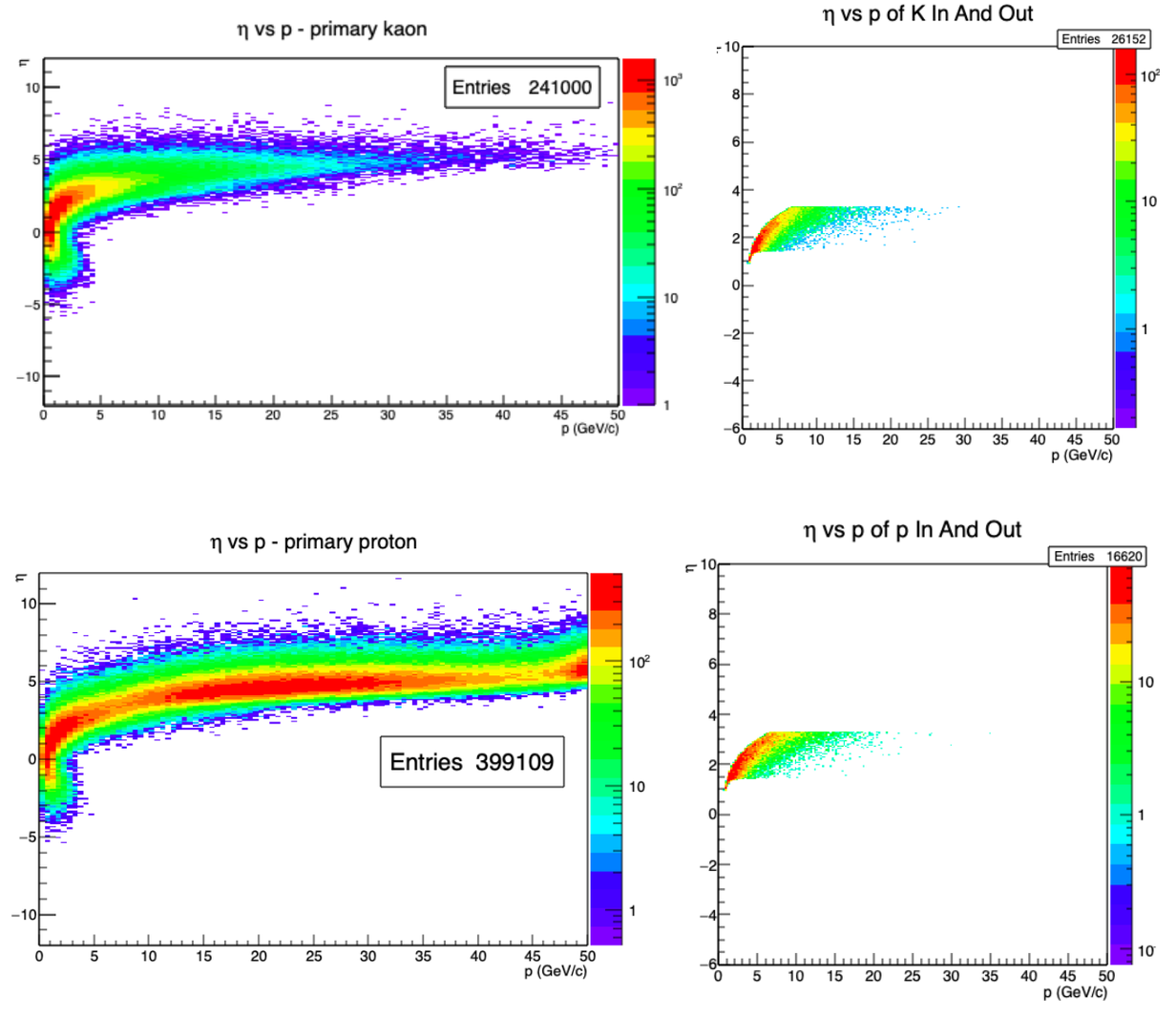
BA

diverse configurazioni di fascio a confronto

PYTHIA 6.4.28
e⁻p collisions
20+250 GeV

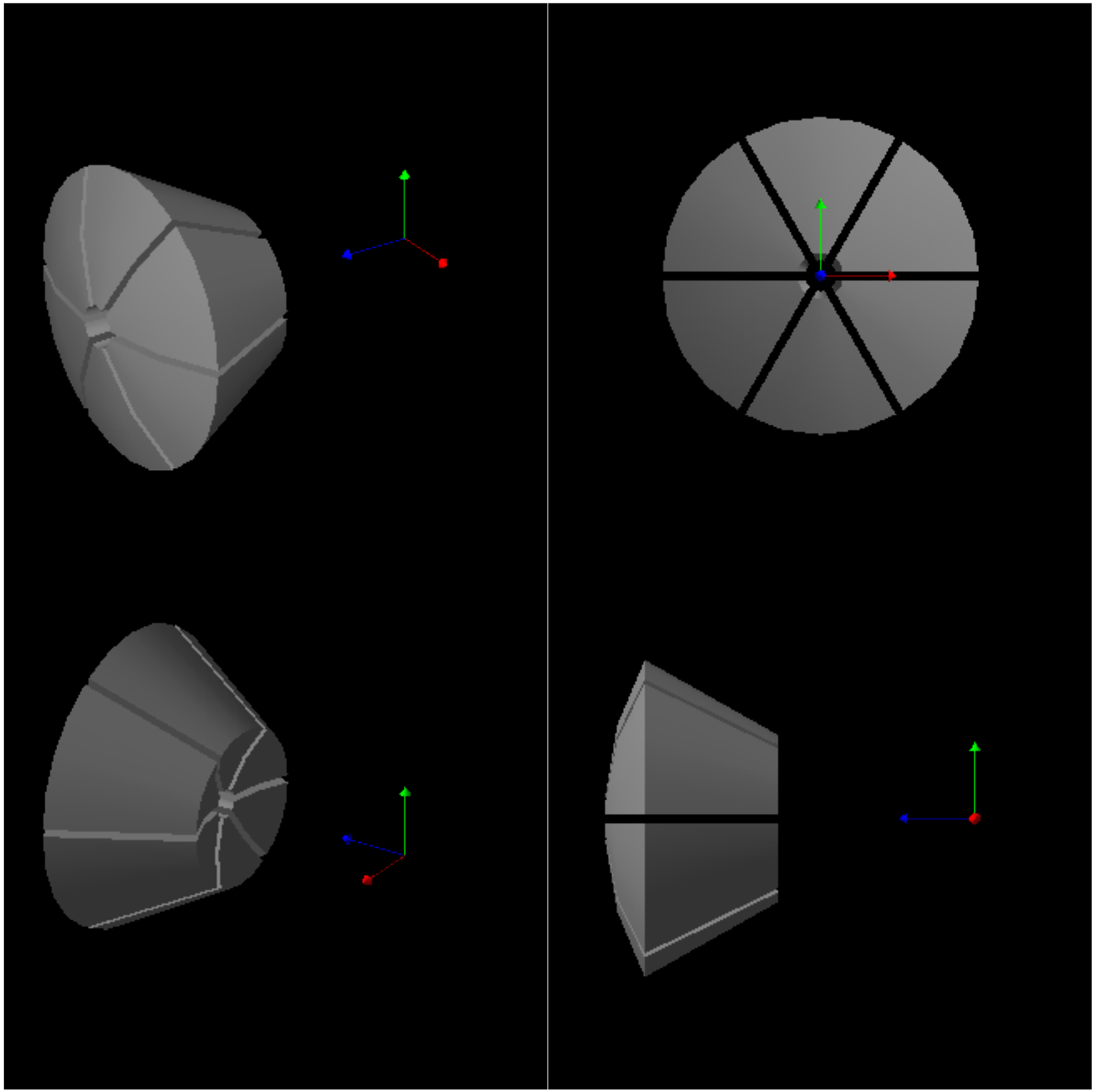


PYTHIA 6.4.28
e⁻p collisions
5+50 GeV



4dRICH

BO



full GEANT4 simulation
with optical physics
B = 2 T solenoidal field
no other materials so far

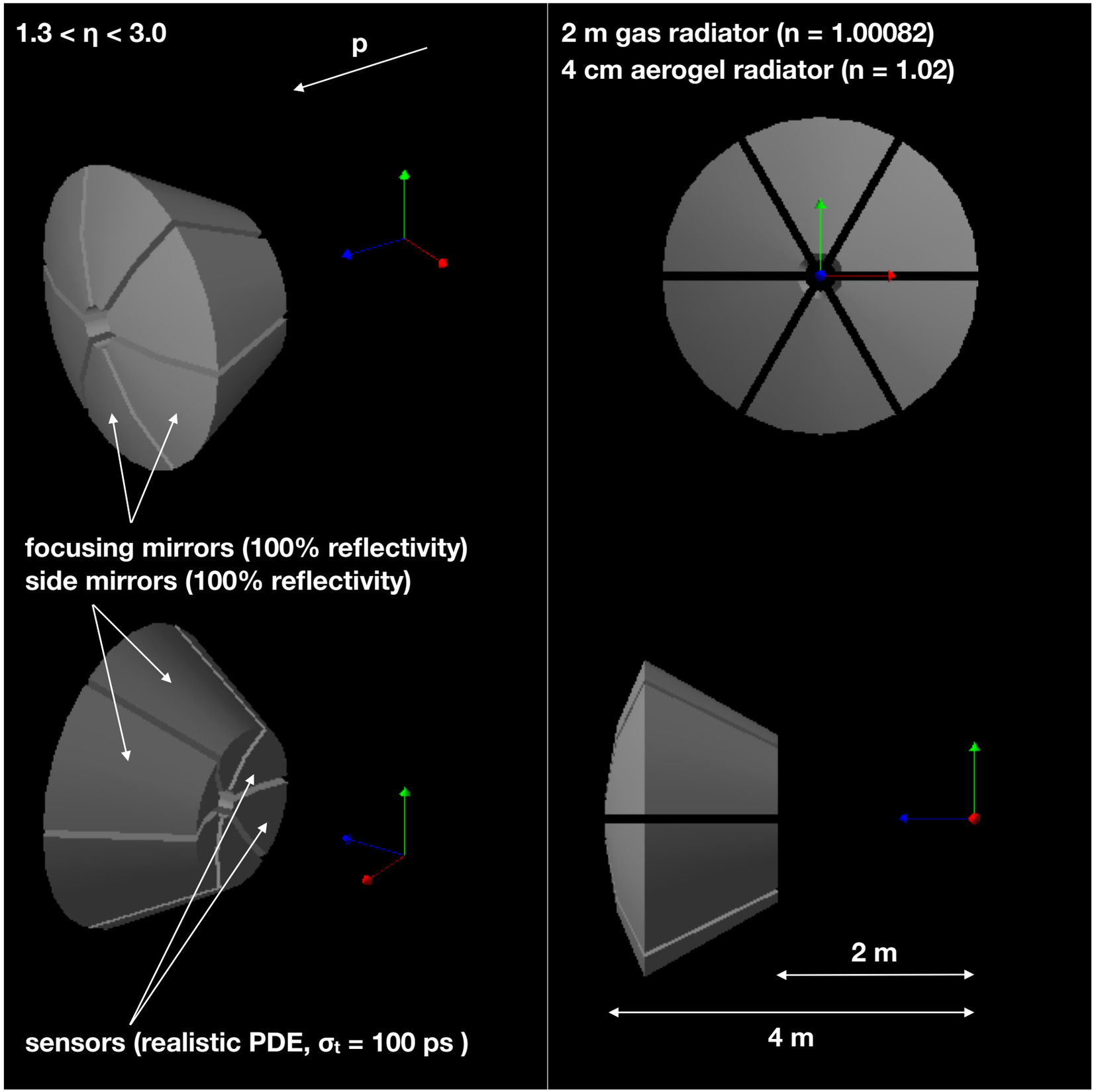
dual-radiator forward
RICH concept
with precision timing
sensors

a preliminary study
still work in progress
testing possible ad-hoc tools
while waiting for common
EICUG-SWG tools

warming up for more
realistic detector studies

4dRICH

BO



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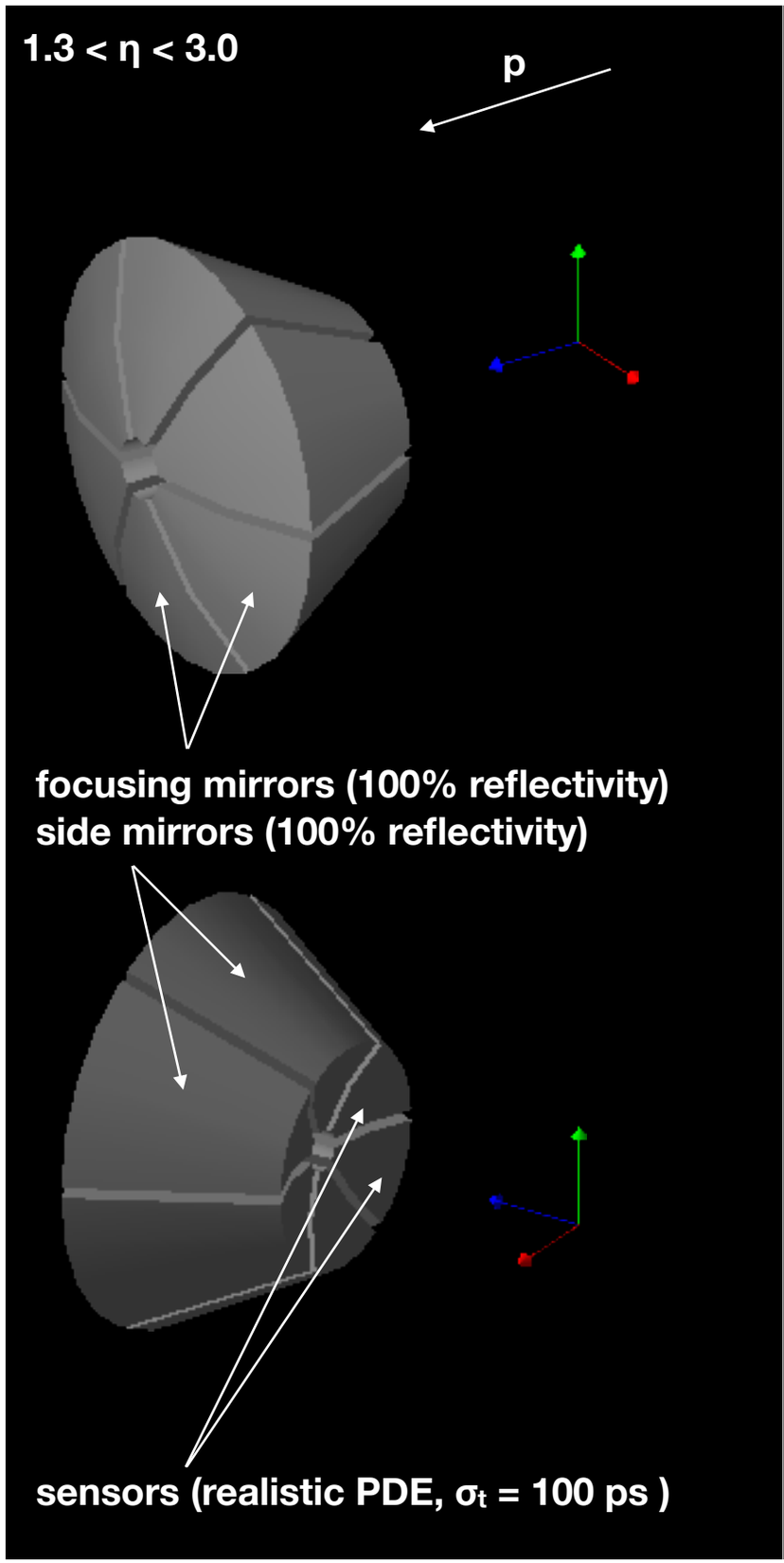
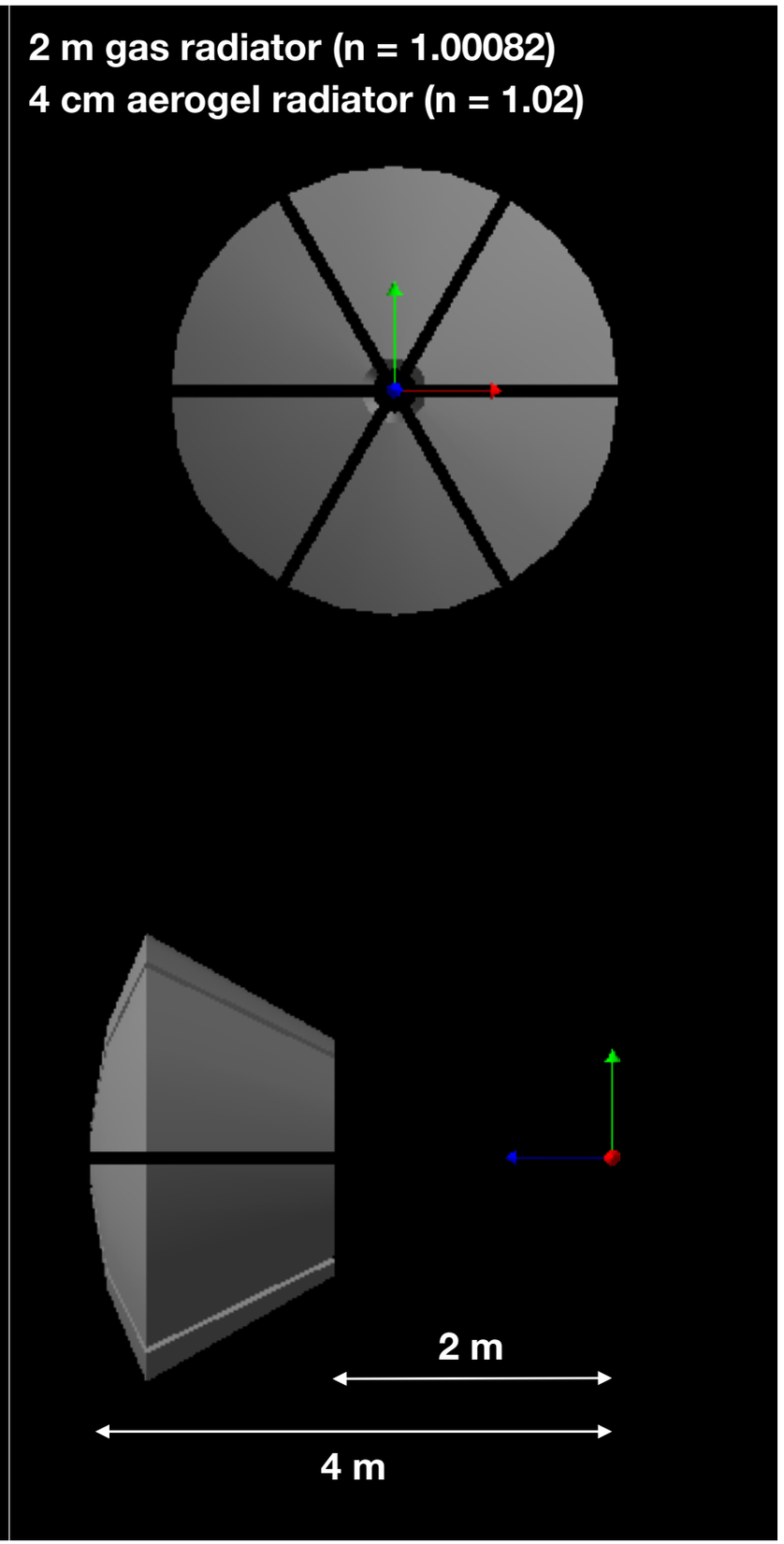
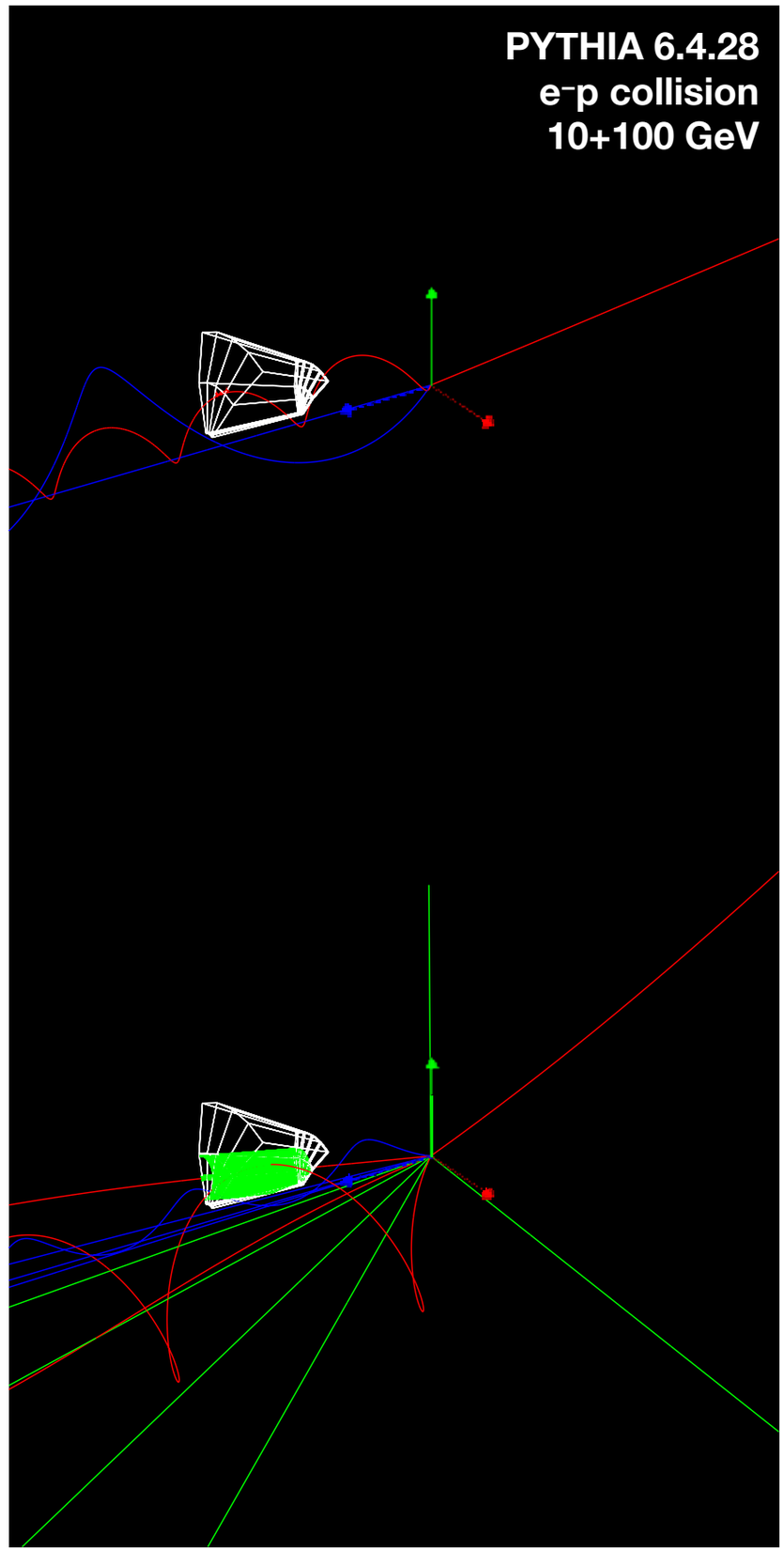

1.3 < η < 3.0
p
focusing mirrors (100% reflectivity)
side mirrors (100% reflectivity)
sensors (realistic PDE, σt = 100 ps)


2 m gas radiator (n = 1.00082)
4 cm aerogel radiator (n = 1.02)
2 m
4 m


PYTHIA 6.4.28
e⁻p collision
10+100 GeV

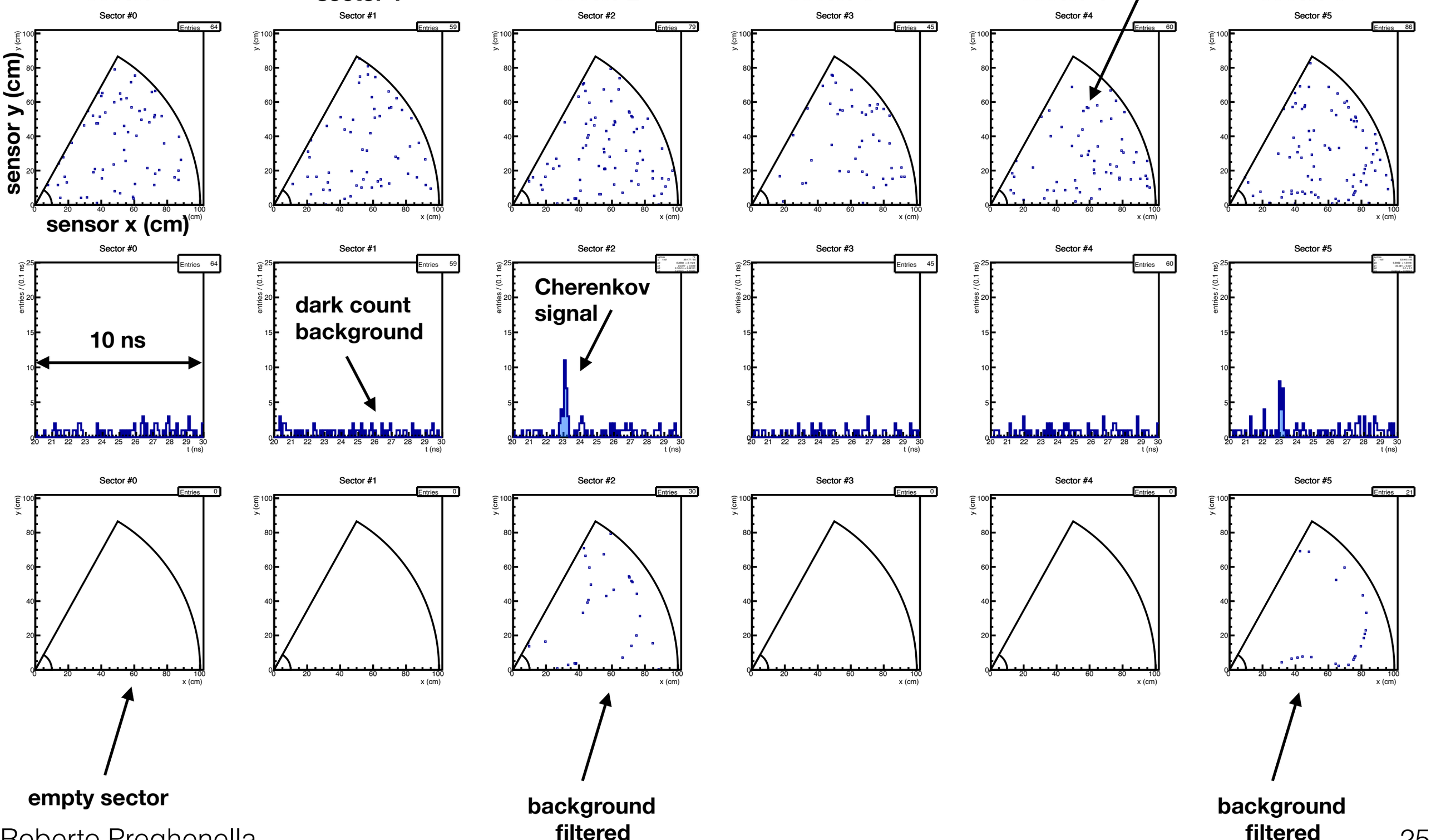
~60k SiPM 3x3 mm² per sector (0.5 m²)
~10kHz dark count rate (100kHz / sensor)
realistic single-photon PDE
100 ps single-photon resolution
10 ns readout snapshots

4dRICH

BO

before timing filtering

sector 0 | sector 1 | sector 2 | sector 3 | sector 4 | sector 5



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4dRICH

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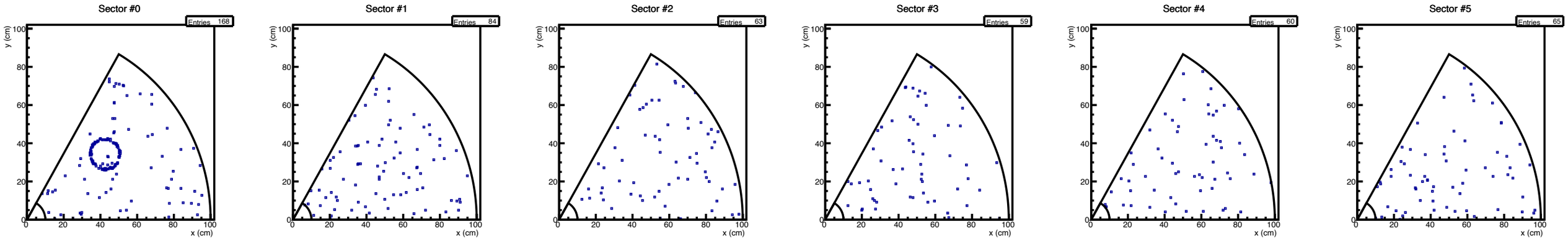
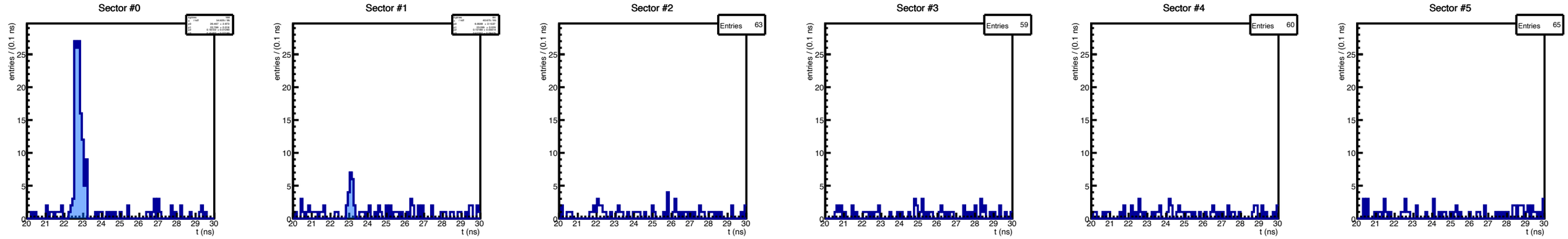
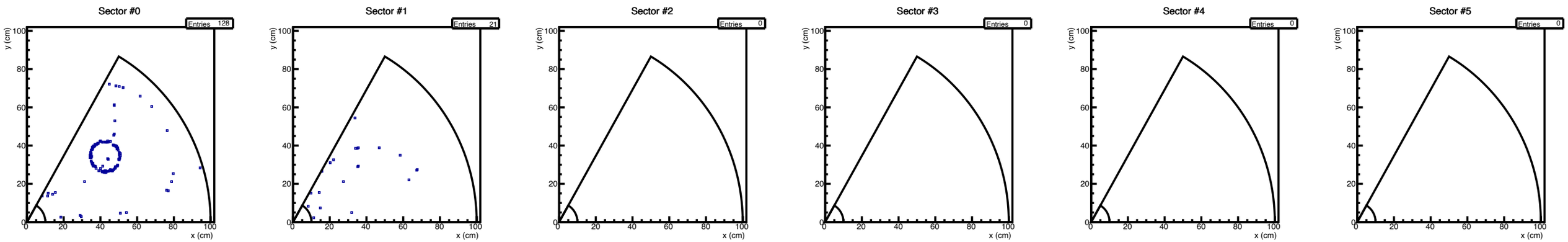






Interessi e casi di fisica

interessi comuni e/o trasversali

- **misura inclusiva di adroni carici identificati**
  → Particle Identification
  → su un largo range di impulso con TOF+RICH

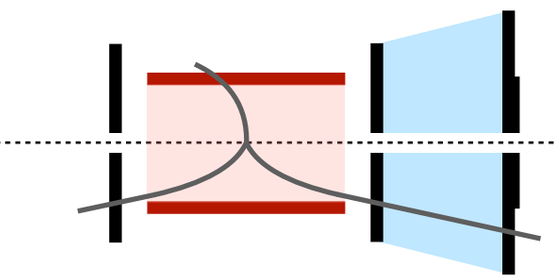
- **ricostruzione di adroni rari**
  → i.e. decadimento a 3 corpi $\Lambda_c \rightarrow p\ K\ \pi$
  → fondo combinatorio significativo
  → identificazione con/senza topologia vertice secondario
  → migliorare la significatività statistica con PID

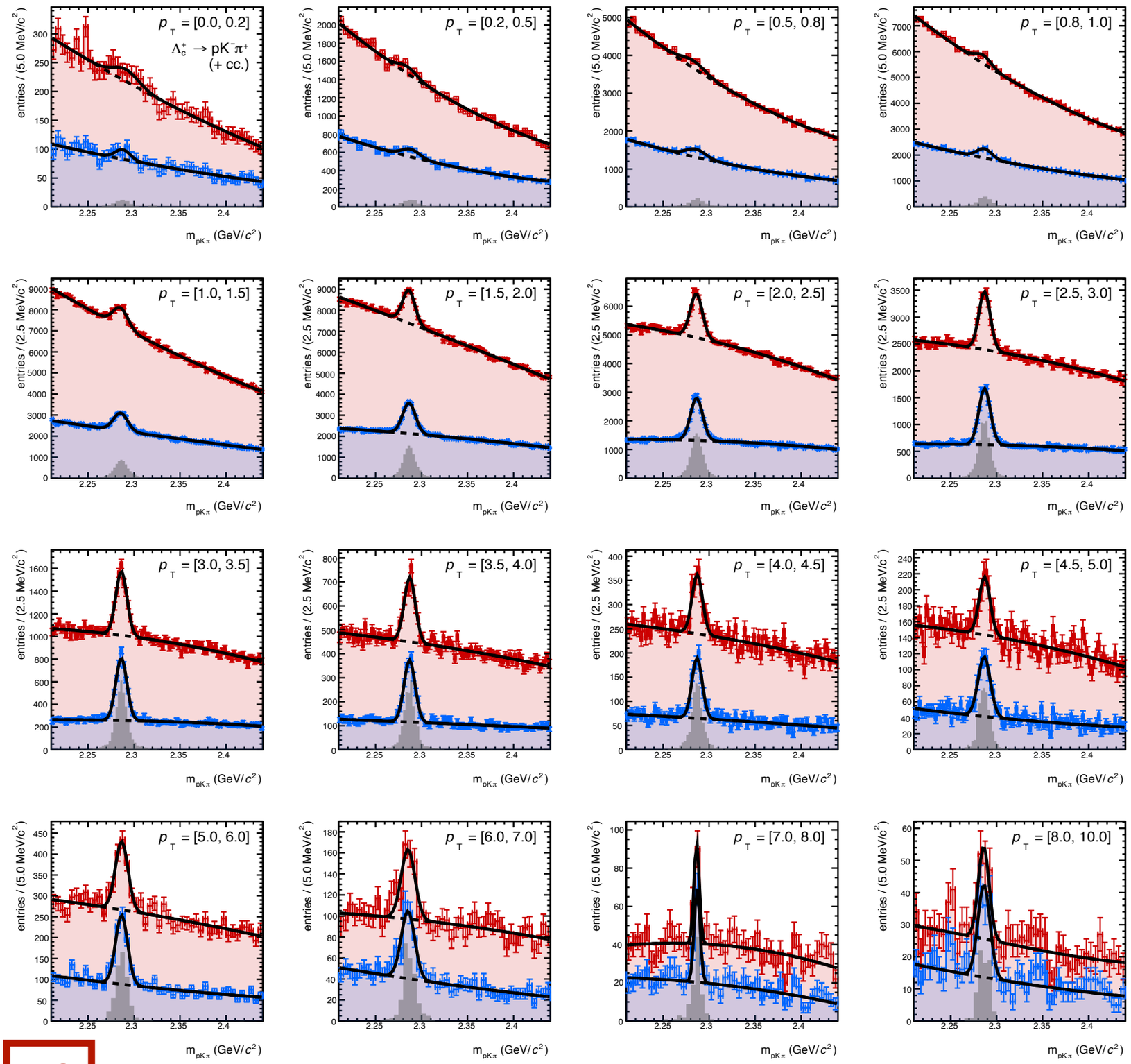
- **spettroscopia adronica**
  → stati esotici a multi-quark / gluoni
  → heavy quarks nella materia nucleare

- **fisica diffrattiva**
  → funzioni di struttura diffrattive

1. no PID
2. inclusive 3σ TOF PID (veto)
3. ideal PID (from MC truth)

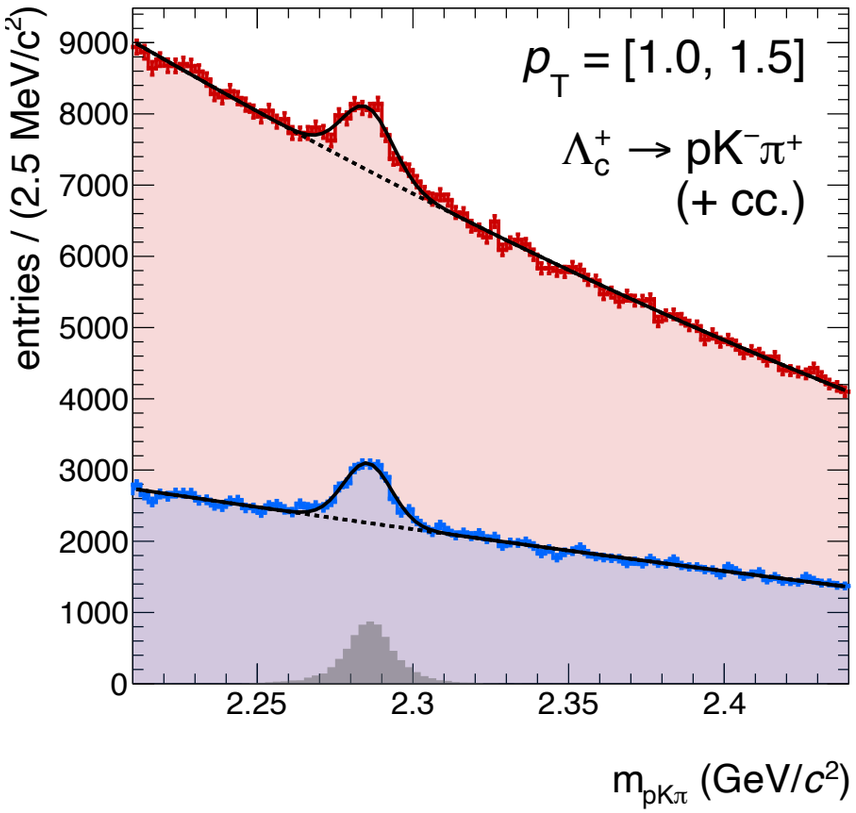
Λ_c reconstruction





$8 < Q^2 < 16$

$0.01 < y_{inelasticity} < 0.95$

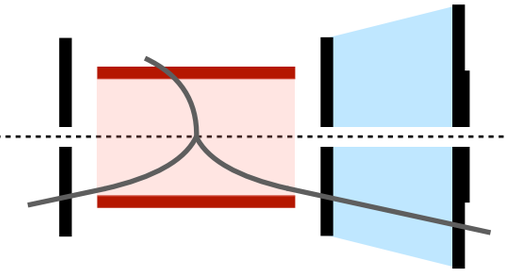


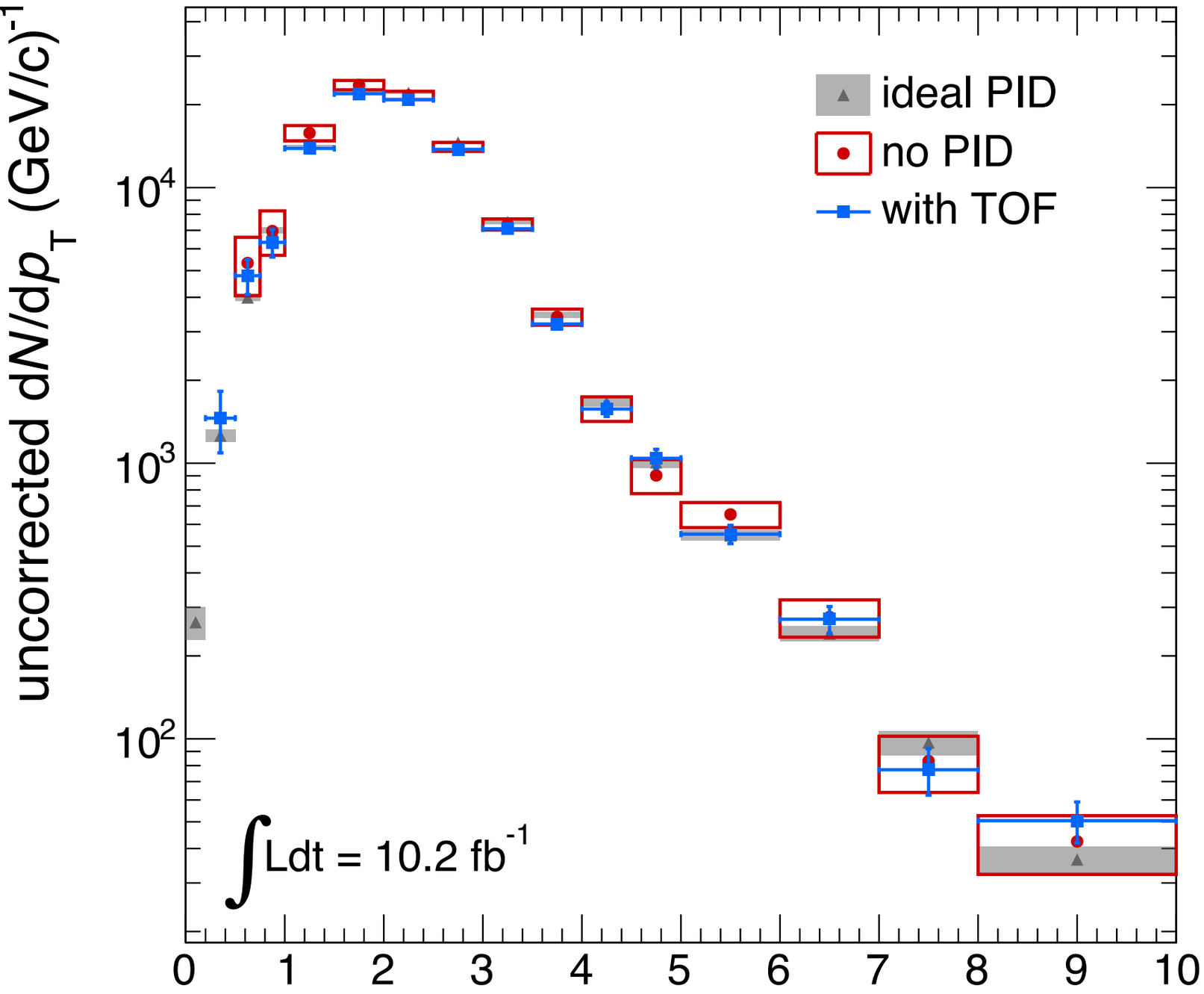
$\int \mathscr{L} = 10$ fb^{-1}

125 d ($\mathscr{L} = 10^{33}$)

1. no PID
2. inclusive 3σ TOF PID (veto)
3. ideal PID (from MC truth)

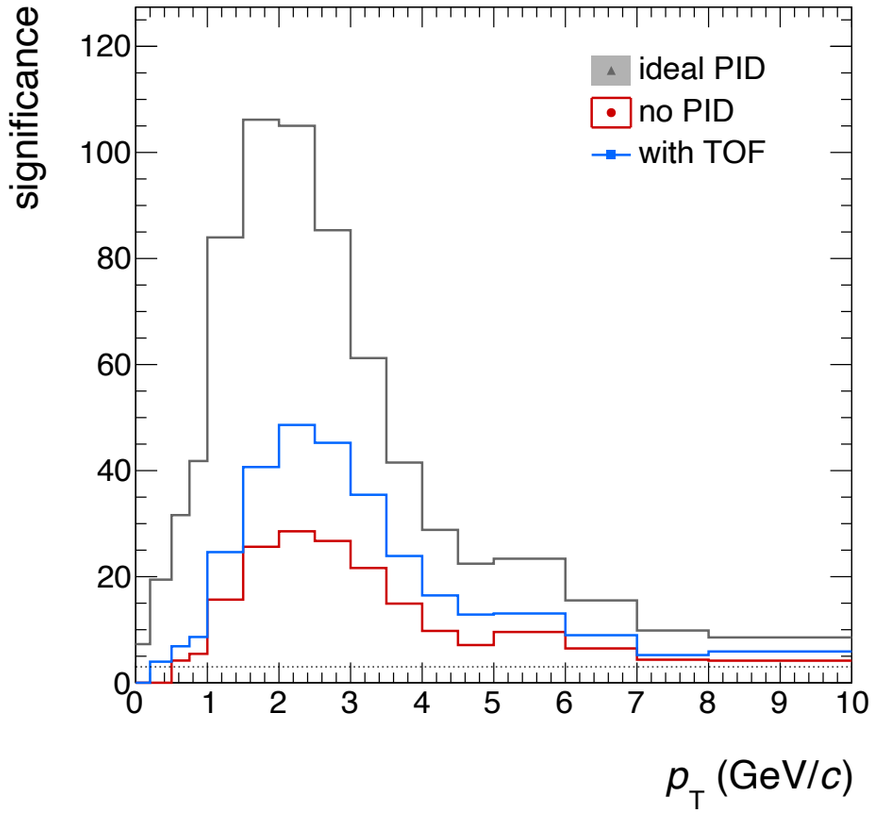
Λ_c reconstruction





$8 < Q^2 < 16$

$0.01 < y_{inelasticity} < 0.95$

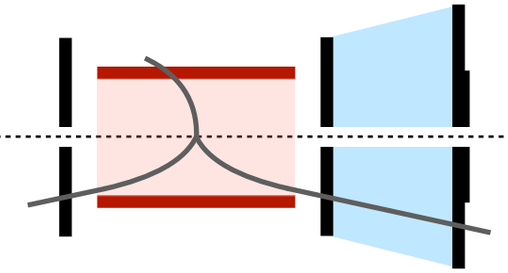


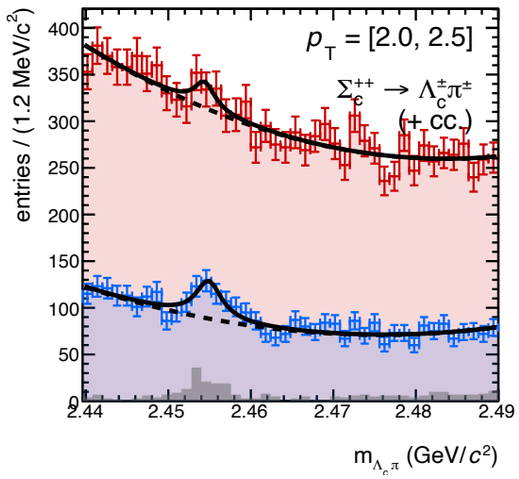
$\int \mathscr{L} = 10\ fb^{-1}$

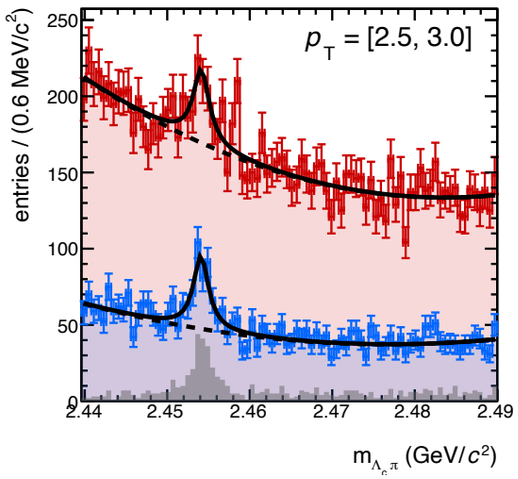
125 d ($\mathscr{L} = 10^{33}$)

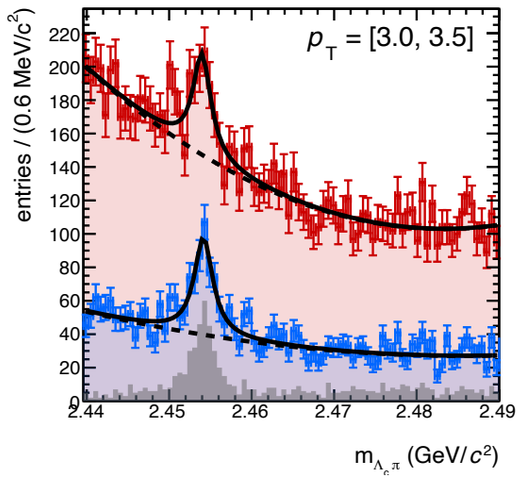
1. no PID
2. inclusive 3σ TOF PID (veto)
3. ideal PID (from MC truth)

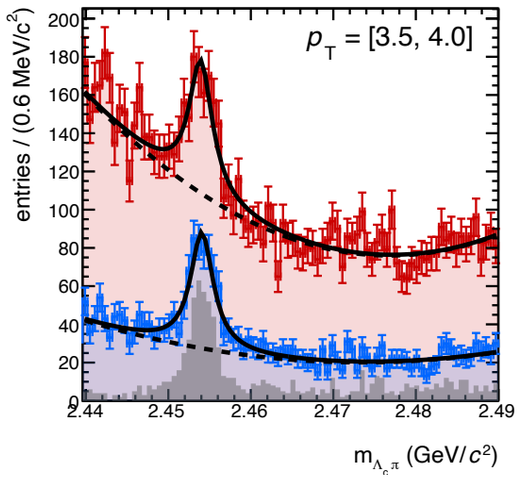
Σ_c reconstruction

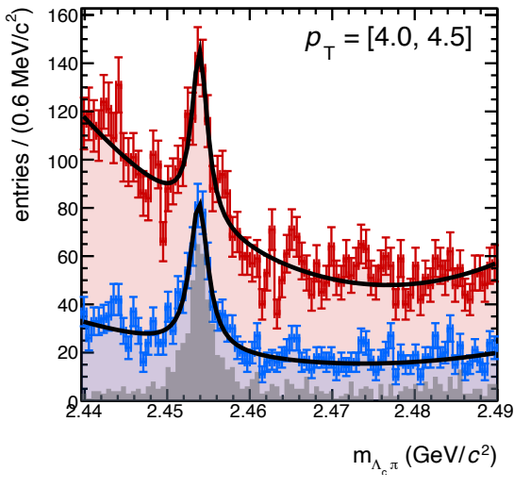


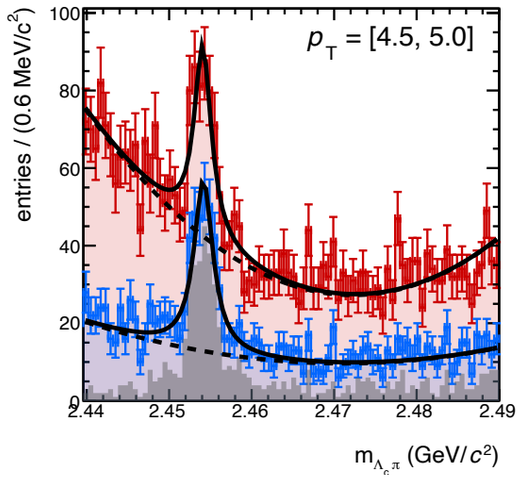


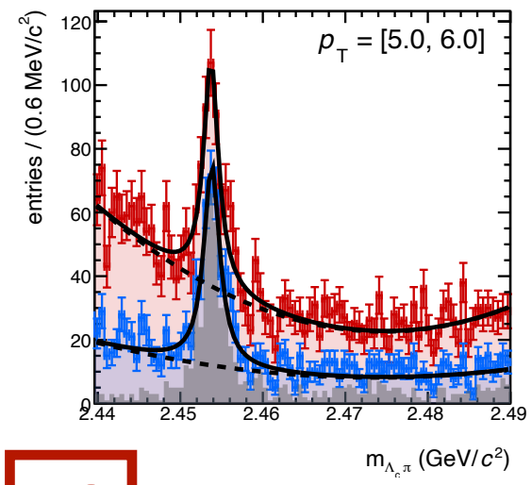


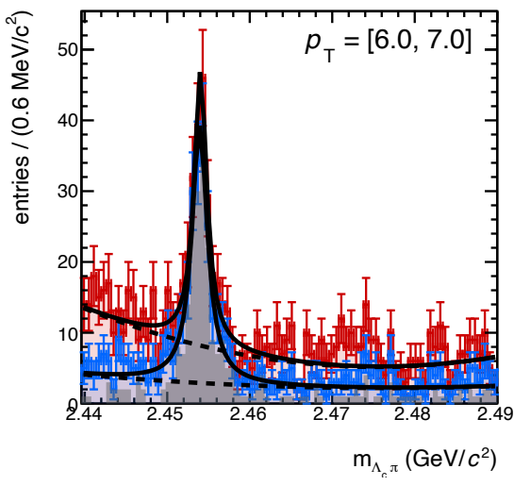


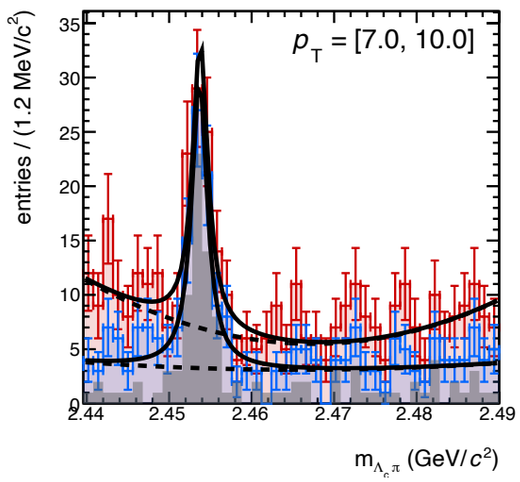






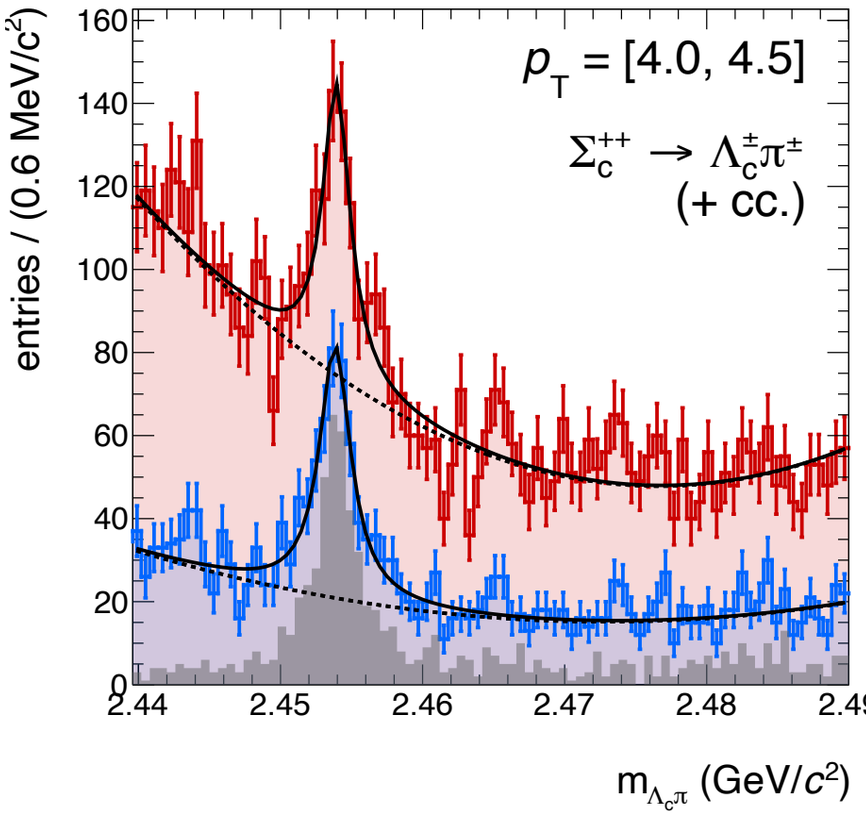






$32 < Q^2 < 64$

$0.01 < y_{inelasticity} < 0.95$



$\int \mathscr{L} = 100$ fb^{-1}

3.5 y ($\mathscr{L} = 10^{33}$)

Spettroscopia adronica

GE

building the hadron spectroscopy community

Goals

- Demonstrate a strong physics case for a hadron spectroscopy program at EIC (to be part of the next EIC physics book)
- Study the impact on EIC design (machine and detectors)

Working groups

- Multiquark & Gluonic states
  conveners: F.K. Guo, R. Mitchell
- Diffractive production
  conveners: W. Schafer, R. McNulty
- Heavy flavor in media
  conveners: C. Weiss, G. Bruno

Spettroscopia adronica

GE

new states to be confirmed

$\tilde{X}(3872)$ as a new state

COMPASS

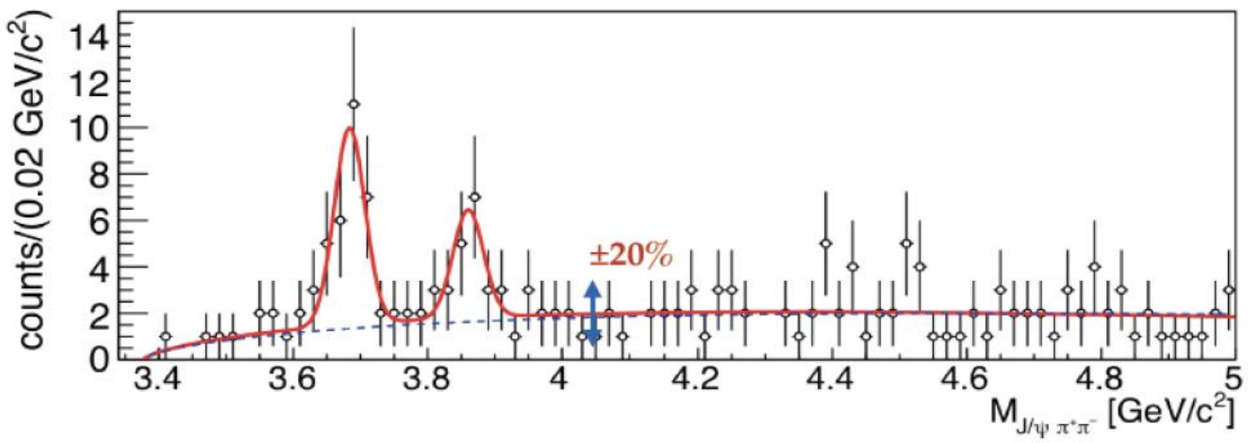
A. Guskov

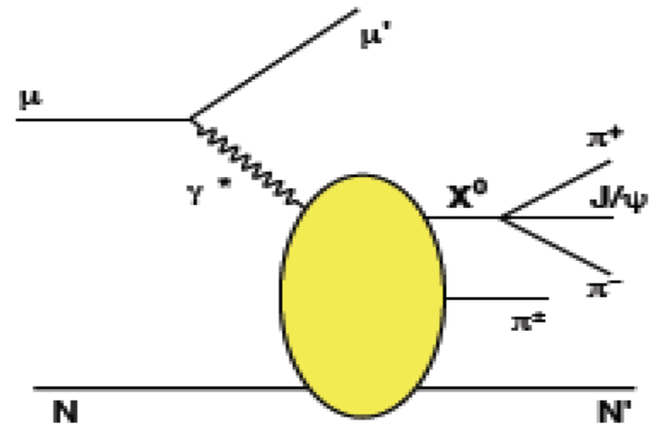
$m_{\tilde{X}(3872)} = (3860.0 \pm 10.4)\ MeV/c^2$

$\Gamma_{\tilde{X}(3872)} < 51\ MeV/c^2\ (CL=90\%)$

Significance (including systematics) is 4.1σ

$C=-1$ (?)





At COMPASS conditions:

$\sigma_{\mu N} \approx \sigma_{\gamma N} / 300$

EIC $L=10^{34}\ cm^{-2}\ s^{-1}$

$e^- N \to e^- \widetilde{X}(3872)\pi^{\pm} N' \to$

$\to e^- J/\psi \pi^+\pi^-\pi^{\pm} N' \to e^-\mu^+\mu^-\pi^+\pi^-\pi^{\pm} N'$

~10 events per day

Inclusive prompt cross section

$$\mathrm{Br}[X \to J/\psi\pi^+\pi^-]\sigma(X(3872), Q^2 > 1\ \mathrm{GeV}) \approx 2.6\ \mathrm{pb} \quad \sqrt{s} = 100\ \mathrm{GeV}$$

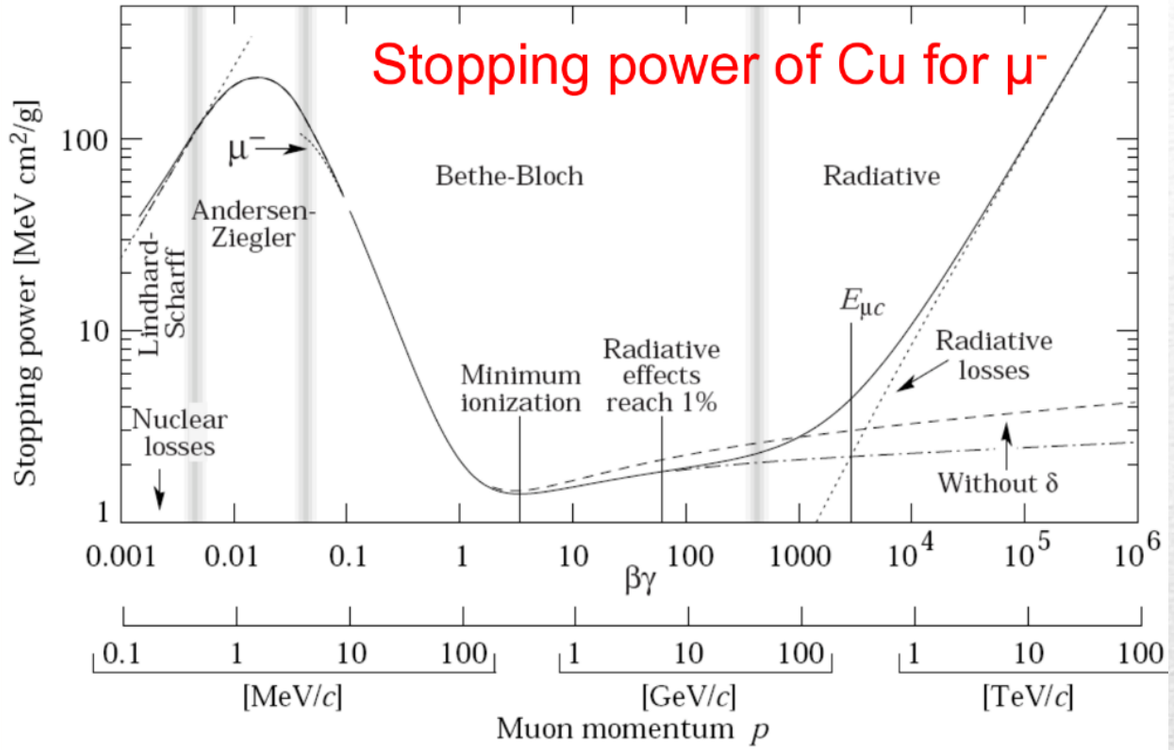
Luminosity: $10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ **0.026 Br*X(3872) per second** X. Yao

Spettroscopia adronica

GE

opportunities with open heavy flavor

- Theory of nuclear modification as a function of momentum transfer ν, virtuality Q - constrained kinematics & B- and D-mesons (mass) to vary formation times
- Stopping power of matter for charged particles is a fundamental probe of its properties. In QED X_0(min) ~ mm, in nuclei 10 orders of magnitude smaller! Transport properties of CNM
- Determination of the production mechanisms for open heavy flavor in SIDIS. Global analysis
- A whole class of new observables to be added – jets and jet substructure



PDG (2008)

- Test unique predictions of QCD
- Determine the cross sections for heavy jet suppression
- Pinpoint the heavy quark mass effect in parton showers

I. Vitev

Conclusioni

- **attività** dei gruppi italiani su molti fronti e **in crescita**
  → presenza importante (co-chair) nel EICUS-SWG
  → partecipazione e aggiornamento costante

- **strumenti** di studio interni e comuni a EICUG-SWG
  → esperienza positiva e risultati con simulazioni Monte Carlo
  → supporto ai contributi INFN su hardware / fisica

- interessi e contributi a studi di **fisica** in costruzione
  → programma spettroscopia adronica
  → fisica diffrattiva
  → interessi trasversali su PID e heavy flavours